APPENDIX I. Off Site Release and Straying Subcommittee Report.

REPORT OF THE SUBCOMMITTEE ON OFF-SITE RELEASE AND STRAYING OF HATCHERY PRODUCED CHINOOK SALMON

January 10, 2001

TABLE OF CONTENTS

INTRODUCTION 1

MECHANISMS AFFECTING HOMING 1

ECOLOGICAL AND EVOLUTIONARY SIGNIFICANCE OF HOMING 3
Definitions 3
Why Home? 3
Why Disperse? 4
Genetic Differentiation among Stocks 4

REPORTED STRAY RATES IN NATURAL POPULATIONS 6

STRAY RATES IN HATCHERY POPULATIONS 7
Central Valley 7
Off-site Release Programs 7
Estimates of Stray Rates 8
Klamath Trinity Basin 11

BENEFITS AND HAZARDS OF OFF-SITE RELEASES 12
Benefits 12
Increased Contribution to Ocean Harvest 12
Reduced competition and predation on local natural spawning populations 15
Hazards and Risks 15
Ecological hazards 16
Genetic hazards 16
Management hazards 17
A qualitative risk assessment 18

CONCLUSIONS 19

RECOMMENDATIONS 19

RESEARCH NEEDS 20

ANCILLARY INFORMATION ON KLAMATH TRINITY 20

AGENCY POLICIES/GUIDANCE REGARDING PRESERVATION OF GENETIC
RESOURCES AND STRAYING OF HATCHERY POPULATIONS 23

REFERENCES 27

I. INTRODUCTION

The migration of Pacific salmon from the ocean to their natal streams to spawn is a behavior that assures maturing adults a high probability of finding appropriate freshwater spawning habitat. Accurate homing behavior results in reproductively isolated populations and allows adaptive divergence to occur among populations. The frequency and extent of dispersal, or straying, from the natal spawning grounds define the demographic and genetic boundaries of a population. Straying is important in colonization and in developing metapopulation structure, and therefore plays an important role in reducing extinction risks.

Both the California Department of Fish and Game (DFG) and the National Marine Fisheries Service (NMFS) have expressed concern regarding the effects of straying of hatchery fish on natural populations (DFG 1998, Myers et al. 1998). "The trucking of hatchery fish in the Central Valley has increased the rate of straying of returning adults, possibly to the detriment of the naturally produced fish. Hatchery fish have been important to maintaining ocean and in-river fisheries, and have incorrectly been perceived as a viable alternative to maintenance of natural spawning populations. Unfortunately, a successful hatchery program can mask the decline in the natural run due to straying of the returning adults, and this appears to be the case for chinook in many areas of the Central Valley and the Klamath River basin." (Boydstun et al. 1992)

A significant portion of Central Valley hatchery reared salmon are transported to the western Sacramento San Joaquin Delta (Delta) and released. Transporting fish downstream of the Delta improves their survival and contribution to fisheries; however, off-site release also increases the straying rate of salmon from the hatchery of origin. This report discusses the potential ecological and genetic effects of increased straying of hatchery produced salmon associated with off-site release programs. It also reviews the results of genetic studies of California's salmon populations, draws conclusions, and makes recommendations to the Joint Hatchery Review Committee.

II. MECHANISMS AFFECTING HOMING

Homing, and therefore straying, may be influenced by such factors as water temperature, flow, presence of other salmon, habitat quality, and so on. Although imprinting is important in homing behavior, straying may have a genetic component: males stray more than females and local populations may home better than transplanted ones (Bams 1976, McIsaac and Quinn 1988). Several studies suggest that older fish stray more than younger fish. It is not clear whether fish that stray actively identify their natal breeding grounds, then migrate elsewhere, or whether strays are unable to find their natal site.

Salmon generally return to the site where they were released (Ricker 1972). Displacement studies suggest that maturing salmon tend to reverse the sequence of olfactory cues they experienced during their seaward migration as juveniles. This process normally returns them to their natal river or hatchery. Depending on the distance of the release site from the rearing site, displaced salmon, upon returning to the odors of their release site, may not detect the odors of their rearing site, and seek the nearest river or hatchery. Solazzi et al. (1991) trucked coho salmon (reared at least in part at Big Creek Hatchery) to release sites below Bonneville Dam (river km 234), and Tongue Point (rkm 29). In addition, smolts were taken by boat in tanks receiving ambient water to the bar of the river (rkm 2), 19 km offshore in the river's plume, 19 km offshore outside the river's plume, and 38 km offshore in non-plume water. These six locations, progressively farther from the rearing site, produced the following proportions of salmon that returned to rivers outside the Columbia River system: <0.1%, 3.4%, 4.1%, 6.1%, 21.0%, and 37.5%.

Salmon are known to imprint on marine as well as freshwater environments; coho salmon trucked from the Little White Salmon Hatchery to Youngs Bay, Oregon, returned to Youngs Bay rather than the hatchery (Vreeland et al. 1975). Imprinting appears to occur up through the time of smolt transformation and precise homing may require smoltification coincident with seaward migration; hence salmon held too long in a hatchery will stray at high rates even though they were given a full opportunity to imprint (Dittman et al. 1996).

Water development in the Central Valley has drastically altered the in-stream hydrology of the Sacramento and San Joaquin river systems. In the upper reaches of both mainstems and tributaries, storage dams for domestic and agricultural water supplies, power generation, and flood control can restrict flows and change their seasonal pattern. Farther downstream, diversion and delivery systems, and flood bypasses can route large volumes of water away from their normal flow configuration. In the Delta, exports for the Central Valley and State Water projects (CVP and SWP) can substantially decrease the proportion of the water flowing toward the ocean. For adult salmonids returning to spawn, these operations can cause delay, misdirection, or obstruction, thus posing problems in homing to their native spawning areas.

Adult spawners must use the Delta as a migrational corridor to the upper Sacramento and San Joaquin rivers and their tributaries. Their orientation depends in large part on an olfactory perception of their home-stream water; a “homing” or “parent” stream odor gradient is required to assure the fish’s return to its natal spawning grounds. CVP and SWP diversion of water at times can cause net reverse flows in the lower San Joaquin River, drafting Sacramento River water into its channels. The mixture of water from both systems in the interior Delta channels may confuse spawners bound for either system, resulting in delay and straying. For Sacramento River fish in particular, their migration can be lengthened, detouring them towards Georgiana Slough and the Delta Cross Channel, with the possibility of ending up in the Mokelumne River (Chadwick 1982).

Adult migrants also face the problem of irrigation return and flood bypass systems that empty confusing mixes of water into main channels. Manmade diversion and reconfiguration of water channels can remove water from a stream’s natural course and discharge it at distantly located streams, channels, or sloughs. Where this occurs, progeny from the stream where the original diversion occurred may be attracted to the water release location during their return. Drainage of water used for agriculture may also contain chemicals that may further confuse salmonid homing senses.

Water management releases may contribute to straying of salmonids if unfavorable water quality conditions result; fish may select a tributary other than that where they were raised if conditions are not acceptable upon return. In general, flows released by storage dams are largely determined by flood control during the winter, and in the spring and early summer by irrigation needs and at times salinity control. The latter operation may deplete the storage of cooler water available during the migration period of late summer and fall. Reduced flows, with accompanying higher than preferred temperatures and dissolved oxygen, may prevent fish from ascending a tributary, and cause them to continue into another .

III. ECOLOGICAL AND EVOLUTIONARY SIGNIFICANCE OF HOMING

After a period of ocean residence, anadromous salmonids return with high fidelity to their birthplace. Accurate homing assures that reproduction takes place in a proven environment and minimizes genetic exchange between geographically and temporally separated stocks. This reproductive isolation allows populations to diverge genetically (due both to drift and selection), and this genetic divergence may be the cause of much of the phenotypic diversity observed within Pacific salmonid species. Homing accuracy is not perfect, however, and dispersal can be advantageous, allowing colonization of new habitats. This section reviews the evolutionary and ecological significance of homing and dispersal.

A. Definitions

For the sake of the following discussion, homing is defined as returning to spawn with others of the same population near the natal area. Straying, or dispersal, in contrast, is spawning somewhere other than the natal area. In the context of evaluating off-site release, stocks with the same run timing in different drainages (e.g, Tuolumne and Stanislaus River fall chinook) and stocks with different run timing in the same drainage (e.g., Butte Creek spring and fall chinook) are considered to be different populations.

B. Why Home?

It is easy to see how natural selection could evolve navigational abilities and high migrational fidelity in anadromous salmonids. Freshwater salmonid spawning habitat is patchy and variable in quality, and adults expend considerable energy in the spawning migration. Once suitable habitat has been located by straying individuals, the ability of fish to return to the location of birth provides a reproductive advantage over individuals that are randomly searching for suitable spawning habitat.

Each phase of the salmon life cycle can be completed only under a narrow range of conditions (flow, water temperature, food availability, etc.) within constrained time periods. For a given stream, there may be narrow windows for upstream migration, egg incubation, juvenile rearing, and downstream migration. If homing accuracy and the initiation time and duration for these phases is heritable (Hard and Heard 1999 provide some evidence for the heritability of homing accuracy) and there is a larger difference among streams than within a stream over time, then there will be additional selection pressure for accurate homing and life history traits compatible with the local stream. Such selection would be expressed as life history diversity that matches the dictates of local environments.

The idea that high migrational fidelity and significant selection pressure in the spawning environment give rise to locally adapted populations is supported by the numerous observations of life history diversity within salmon species and even within drainages (Myers et al. 1998 contains a summary for chinook). In some cases, phenotypic differences have been shown to have a genetic component. Examples include directional orientation of inlet- and outlet-spawning sockeye (Quin

1985) and swimming endurance of coho from different streams raised in a common environment (Taylor and McPhail 1985). It is quite possible, however, that a portion of this diversity is phenotypic plasticity rather than local adaptation (Adkison, 1995), although the generally poor success of stock transplants (e.g., Reisenbichler 1988) suggests that local adaptation is real.

C. Why Disperse?

All species express a strong tendency to expand their range through dispersal. Every species has at least one dispersal stage in its life history (Mayr 1966). Salmon are no exception and disperse themselves through the process of straying. Straying provides for exchange of individuals between populations and allows the rapid colonization of unoccupied areas (e.g. New Zealand or the Great Lakes; see Quinn 1984, Milner and Bailey 1989). In general, however, it appears that straying migrants have limited success reproducing in new habitats when those habitats are already occupied by conspecifics. Tallman and Healey (1994), studying chum salmon from Vancouver Island, found that stray rates inferred from allozyme variation were lower than straying rates estimated directly from mark-recapture studies, and concluded that strays had lower reproductive success than fish returning to their natal streams. Stray fish may face barriers in mating with local fish or preferentially mate with one another; hybrid offspring may be less viable.

D. Genetic Differentiation among Stocks

Over time, frequencies of selectively neutral alleles in reproductively isolated populations tend to diverge due to genetic drift. Genetic drift is opposed by dispersal between populations. Allele frequencies can therefore be used to study population structure, and have been used to define conservation units (e.g., Myers et al. 1998). An implicit assumption is that if there is enough reproductive isolation to allow genetic drift, then local adaptation is possible. Genetic diversity is the result of local adaptation, and NMFS considers maintenance of within- and among-ESU[1] diversity critical in the conservation of ESUs and Pacific salmonid species (McElhany et al. 2000). In this subsection, we review studies of the genetic diversity of California's salmonids. Studies to date have focused on determining large-scale population structure (differences associated with major ecoregions) rather than fine-scale structure (diversity within a basin).

Utter et al. (1989) used allozyme variation to study chinook populations ranging from California to British Columbia. Within California, chinook from coastal watersheds, the Klamath-Trinity basin, and the Central Valley formed clusters distinct from each other and other west-coast chinook populations. In general, it appears that run time variation has arisen separately within basins, i.e., as an adaptation by the local ancestral stock rather than by dispersal.

Bartley and Gall (1990) present an analysis of allozyme variation in 35 populations of chinook from northern California. Within the Central Valley, there appears to be some degree of reproductive isolation between populations, and some samples (from a specific watershed or hatchery) contained alleles not found in some or all other Central Valley samples. Interpretation of this study is difficult because samples were primarily juveniles and might be mixtures of different races or populations (including hatchery populations).

[1] An ESU (evolutionarily significant unit) is a population of salmon determined by NMFS to meet the definition of a "species" for purposes of listing under the ESA.

Gall et al. (1991) examined 78 isozyme loci in 37 chinook populations from California and Oregon. Central Valley populations formed a cluster distinct from other populations (California and Oregon coastal, Klamath). Within the Central Valley, data suggests there are about 15 migrants between populations per generation, which may reflect egg and fingerling transfers between hatcheries. Changes in allele frequencies were observed over time.

Nielsen et al. (1994a) documented differences in mtDNA genotypes and allele frequencies for 4 (3 hatchery, 1 natural) samples of Central Valley chinook. The natural population (a mixture of Mill Creek, Deer Creek, upper Sacramento and American Rivers) had an allele not found in any of the hatchery samples, and each of the hatchery samples had alleles not found in the natural samples, indicating isolation between hatchery and natural samples.

Nielsen et al. (1994b) looked at mtDNA polymorphisms in 312 samples taken from 7 populations of Central Valley chinook, including fall-, winter- and spring-run samples. They found significant differences between run timings, but no significant differences among fall-run hatchery populations. Dizon et al. (1995) caution against accepting the null hypothesis of no significant difference between populations without consideration of the statistical power provided by the sample.

Kim et al. (1999) examined major histocompatibility complex differentiation in Central Valley chinook using 4 alleles. The authors found that winter and spring chinook were significantly different than fall and late fall; no samples were taken to allow differentiation within the fall run to be examined.

NMFS (1999, unpublished update to status review summarized in 64 FR 50394; 2000, David Teel, personal communication) obtained additional allozyme samples for some California populations and added them to the analysis presented in the chinook status review (Myers et al., 1998). Winter and spring chinook samples were well-separated from the fall chinook cluster. Within the fall chinook cluster, four sub-groups were evident: 1) Merced River and Merced Hatchery, Tuolumne River and Nimbus Hatchery; 2) Feather River Hatchery fall and spring, Coleman National Fish Hatchery (CNFH) fall, and upper Sacramento late fall; 3) CNFH late fall; 4) Stanislaus River. G-tests of differences in allele frequencies were significant, with the exception of the following comparisons:

1. Tuolumne River - Merced River
2. Tuolumne River - Merced Hatchery
3. Tuolumne River - Nimbus Hatchery
4. Deer Creek Spring - Feather River Hatchery Spring

Finally, Banks et al. (2000) used DNA microsatellites to study the population structure of Central Valley chinook. They found that winter chinook were quite different from other runs, and that Butte Creek spring run chinook are distinct from spring-run from Mill and Deer Creek, as well as other chinook runs. Late fall-run chinook are similar to, but significantly distinct from, fall-run chinook. They found little differences among fall chinook populations; fall chinook appear to form a random-mating system throughout the valley. They present evidence for hybridization of fall and spring run fish within CNFH, and suggest that there are no genetic spring chinook in the Feather River Hatchery, in spite of the presence of chinook with a spring-run phenotype.

Taken together, the Banks study and NMFS coast-wide allozyme data paint a consistent picture. One point is that there are genetically distinct populations within Central Valley chinook, composed of winter chinook, Butte Creek Spring chinook, Mill/Deer Creek spring chinook, and fall/late fall chinook. The apparent lack of geographic structure of fall chinook within the Central Valley is in striking contrast with other chinook ESUs, where genetic structure corresponds closely to geographic structure of watersheds. One hypothesis in accord with this observation is that the history of stock transfers and off-site release in the Central Valley has resulted in homogenization of fall chinook. The other explanation for this pattern is that for some reason, Central Valley fall chinook, unlike other chinook from the Central Valley or anywhere else, naturally have weak homing tendency, perhaps because this is advantageous at the edge of the range

The data gathered to date has some serious gaps. The lack of adequate fall chinook samples from Mill, Deer and Butte Creeks should prevent us from making a final conclusion about homogenization of fall chinook and about the status of spring chinook in the Feather River. In general, spring chinook throughout the Pacific northwest are often most similar to fall chinook from the same basin, indicating that spring and fall chinook in a basin share a common ancestor. The divergence of Butte Creek from other spring chinook in the Central Valley and the similarity of spring and fall chinook in the Feather River are consistent with this. By corollary, we might predict that fall chinook in Mill, Deer and Butte Creek will show some similarity to spring chinook from these basins, and that they therefore will be different from other fall chinook populations.

At first glance, one might suppose that elevated straying between hatchery and natural populations is not a problem, since much of the damage (loss of any local adaptation) has been done. We could, however, hypothesize that if straying ceased, natural selection would lead to local adaptation (and therefore population differentiation) and increased productivity of natural populations. As discussed in the risk assessment section, hatchery straying poses genetic risks to natural populations beyond merely the reduction of genetic diversity through spatial homogenization. Furthermore, Mill, Deer and Butte Creek may harbor genetically distinct fall chinook populations that could be an important component of fall chinook genetic diversity, and it would be precautionary to protect this diversity.

IV. REPORTED STRAY RATES IN NATURAL POPULATIONS

Because of the relative ease of tagging hatchery fish, most estimates of straying come from hatchery populations and relatively fewer exist for natural salmon. Table 1 displays the the considerable differences in stray rates in natural populations that have been reported among rivers and species. For example, Shapovalov and Taft (1954) observed considerably higher rates for coho populations (15-27%) in central California coastal streams than have been reported for several Vancouver Island natural coho populations (0-3.9%, Labelle, 1992). Because estimates of straying will vary depending on the study design and how straying is defined, the determination of a “natural” rate of straying is difficult and probably not particularly useful.

Table 1. Estimates of straying (the percentage of marked fish returning to a location other than that in which it was marked) for Pacific salmonids. - from McElhany et al. (2000).

Species	% Straying	Geographic scale of straying[1]	Origin	Reference
Sockeye	0.6 - 1.5	Cultus Lake, British Columbia	Natural	Foerster 1968
Chum	2.2 - 10	350 - 2000 km	Natural	Sakano 1960
Chum	17.4 - 54	British Columbia	Natural	Tallman & Healey 1994
Chum	5.2 - 5.4	British Columbia »10 km	Hatchery	McQuarrie & Bailey 1980 (Quinn 93)
Coho	15 – 27 0 – 3.9 1 – 65 0 - 67	Scott and Waddell: 10 km; B C: 9 – 159km; Puget Sound: <150 km; WA coast: <150 km	Natural	Shapovalov & Taft 1954 Labelle 1992 Vanderhaegen & Doty 1995
Coho	0.0 - 27.7 1 – 7 <0.5 – 4 0 – 12.4	British Columbia: 7-58 km Puget Sound: <150 km; WA coast: <60 km; Columbia: <150 km	Hatchery	Labelle 1992 Vander Haegen & Doty 1995
Steelhead	2 - 3	Scott and Waddel 10 km	Natural	Shapovalov & Taft 1954
Chinook (fall)	3.2	> 60 km but w/in Columbia basin	Natural	McIsaac 1990
Chinook (fall)	4.6 – 5.7 7 - 10 40 - 86 8 54 < 3 2 – 25 1.2	Lewis: w/in Columbia basin; On-site release Sacramento: 48-336 km Off-site release Sacramento: 48-336 km On-site release Sacramento Off-site release Sacramento Puget Sound: <150 km WA coast: <150km SE Alaska > 7 km	Hatchery	Quinn et al. 1991 Cramer 1989 Cramer 1989 Dettman & Kelly 1987 Dettman & Kelly 1987 Vander Haegen & Doty 1995 Hard & Heard, 1999
Chinook (spring)	0.3 - 3.6	98.3% w/in 50 km, 1.7% out of Columbia basin	Hatchery	Quinn & Fresh 1984
Coastal cutthroat	0 - 30	Oregon Coastal 70-150 km	Hatchery	Giger 1972

1 Geographical scale of straying refers to the distance from the spawning area, or point of release, that the study defined as constituting "straying"

II. STRAY RATES IN HATCHERY POPULATIONS

A. Central Valley

1. Off-site Release Programs

The production and release of fish from large scale salmon hatcheries in California during 1999 was approximately 47.8 million salmon and 2.8 million steelhead. About a quarter of the 1999 chinook production (approximately 11.6 million) was transported by truck and released west of the Delta. Three California State hatcheries located in the Central Valley (Feather, Mokelumne, and Nimbus hatcheries) accounted for roughly 99% of the off-site releases, with San Pablo Bay being the primary destination. Merced Hatchery production is released within the San Joaquin basin, above Jersey Point. Approximately 6,600,000 salmon received coded wire tags prior to release while 100% of the steelhead received adipose fin clips.

2. Estimates of Stray Rates

The number of published estimates of stray rates for Central Valley hatchery salmonids is limited. The many studies involving marked hatchery fish, particularly those conducted in the 1970s and 1980s, were intended to evaluate release strategies through examination of contribution rates to ocean fisheries and inland returns.

Hallock and Reisenbichler (1979) estimated "relative homing tendencies" of CNFH and Nimbus Hatchery chinook salmon released at their respective hatchery compared to releases at Rio Vista. Homing tendency was defined as the quotient of the ratios of the hatchery recoveries to ocean recoveries for fish released at Rio Vista and at the hatchery:

$$\frac{(HatcheryRecoveries_{RioVistaRelease}/OceanRecoveries_{RioVistaRelease})}{(HatcheryRecoveries_{HatcheryRelease}/OceanRecoveries_{HatcheryRelease})}$$

They reported that the homing tendency for CNFH fish released at Rio Vista was only 18% that of fish released at the hatchery, while the homing tendency of Rio Vista-released Nimbus fish was 74% that of fish released at the hatchery. Comparative returns or dispersal of returning fish from off-site releases was qualitatively recognized as substantial straying in CNFH steelhead (Hallock 1980), and chinook salmon from Mokelumne River and Feather River hatcheries (Meyer 1984, 1987).

Analyses of data for coded-wire tagged salmon (which included some of the above studies) have provided some chinook straying rates. Dettman and Kelley (1987) estimated that the proportion of Feather River Hatchery produced spawners returning to the Feather River was 92% for fish released from the Feather River Hatchery into the Feather River and 46% for fish transported and released in the Delta and estuary, that is straying rates of 8% for fish released at the hatchery and 54% for fish released in the Delta. Their estimate assumed the number of stray rates to other rivers were proportionate to the fraction of Feather River Hatchery tags observed in hatcheries on those rivers. Based on this relationship and the results of Hallock and Reisenbichler (1979), they speculated that stray rates for Nimbus fish released on-site and in the estuary would be 8% and 32%, respectively. An alternative analysis of coded wire tag (CWT) data by Cramer (1989) estimated Feather River Hatchery chinook stray rates of 7% from on-site releases and 69% for those released in the estuary, and rates for CNFH fish of 10% and 86% for releases on-site and at Knights Landing, respectively.

In comparing on-site hatchery and releases of yearling fall chinook salmon from the Feather River Hatchery, Sholes and Hallock (1979) reported a 10% stray rate for fish released on-site compared to a 70% stray rate for releases made near Sacramento.

The U.S. Fish and Wildlife Service (USFWS) recently developed a straying index for groups of fish released at varying distances from CNFH (USFWS, 2001). The index assumes that the effects of release location are limited primarily to 1) the survival rates of smolt to recruits and 2) the stray rates of returning adults. If release location does not affect ocean distribution and catch rates, then two release groups from the same broodyear should generally experience similar catch rates; differences in observed catch rates would presumably be due to differences in the straying rate. Catch rates are defined as ocean recoveries/(ocean recoveries + hatchery recoveries + unknown strays), and hatchery recoveries include fish returning to Battle Creek. If two release groups are similar except for location of release then differences in catch rates can be accounted for by estimating the number of additional strays necessary to produce equal catch rates. The stray index is then calculated as the strays/(strays + hatchery recoveries). Note that in the data presented here, the number of unknown strays for groups released at CNFH are not estimated, that is the stray rate is arbitrarily set at zero, and the stray index for groups released at CNFH, 0.0, represents the actual unknown stray rate for fish released at the hatchery.

Beginning in the late-1970s and into early 1990s, the USFWS released experimental groups of fall chinook juveniles reared at CNFH at various sites in the Sacramento River and the Delta. These off-site releases were performed primary to test whether the contribution to ocean fisheries (i.e. survival from release to recruitment to fisheries) could be increased without reducing the hatchery returns below that needed for hatchery broodstock requirements. These studies showed that ocean fishery contribution rates from releases made in the western Delta were generally higher than ocean contribution rates for releases made at the hatchery or in the upper Sacramento River. However, the rates of return to the hatchery of fish released in the western Delta were generally equal to or sometimes less than for than those released at the hatchery. It was also quite evident that high straying rates were occurring with the Delta releases and that the resulting strays were not limited to the upper Sacramento River. The studies showed, during some years, minimum brood stock needs at the hatchery would be met only by releasing fish at the hatchery because the high rates of straying associated with Delta released fish was not overcome by the apparent increase in survival.

In 1989, the USFWS made a decision to truck all of the CNFH fall chinook production fish to the City of Benicia because of very poor in-river low flows, drought-related conditions, and high Delta exports. In 1990, with the continuation of the drought and poor in- river conditions, the production was again trucked down river. However in that year, because Delta exports were being curtailed combined with the concerns of the possibility of not getting enough broodstock back to the hatchery, only half of the production was released at Benicia, with the remaining half released at Princeton Ferry (rm165) on the Sacramento River. In 1991, the poor in-river drought related conditions continued but because Delta exports were further curtailed, all of the production was released at Princeton Ferry. In 1992, in-river conditions returned to more normal conditions and the hatchery returned to its usual practice of releasing nearly all of their production fish at the hatchery. Since 1992, all fall chinook production fish have been released at the hatchery.

Fall Chinook Salmon Analysis of mean stray indices for broodyear 1980 through 1987 fry releases and broodyear 1980 through 1986 smolt releases (Table 2) suggested a disruption in the imprinting cycle seemed to have a greater effect on fry releases. Fry releases made at the Red Bluff Diversion Dam (RBDD) resulted in a stray index more than double that of smolt releases. Releases of marked smolts from broodyears 1987 to 1991 were part of a site of release evaluation conducted in cooperation with the DFG. Analysis of the data demonstrate releases of fish west of the Delta result in higher ocean contribution rates and likely overall survival than upstream releases. However, the drawback of the survival advantage is that a high percentage of returning fish from downstream release sites “stray” (stray index 75.3%) presumed again to be due to the interrupting of the imprinting process. Physical evidence of increased straying associated with the downstream release groups from this study has been collected. Eighteen “strays” from the Benicia

Table 2. Summary Table for Mean Stray Indices for Releases of Cnfh Fall Chinook Salmon Smolts and Fry. Number of Groups Examined Are in Parenthesis.

Release Location	Stray Index (%)		
	Broodyear 1980 - 1987	Broodyear 1980 - 1986	Broodyear 1987 - 1991
Battle Creek	0.0 (4)	0.0 (12)	0.0 (5)
Red Bluff Diversion Dam	47.2 (11)	26.3 (12)	8.4 (5)
Princeton			36.1 (5)
Various Downstream Locations	79.3 (15)		
Benicia			75.3 (5)
Mokelumne River	89.7 (5)		

release groups were encountered during various field surveys or hatchery operations. Locations of these recoveries include: Clear Creek (1), Feather River (4), American River (8), Mokelumne River (3) Tuolumne River (1), and Merced River (4). Two "strays" from the Princeton release groups were also encountered in Clear Creek, while no strays were recovered/reported from the RBDD release groups or the on-site Battle Creek release groups.. All results of the broodyear 1987 - 1991 site of release evaluation can be found in Niemela (1996).

Late-fall Chinook Salmon Broodyears 1993 - 1995 were used in the analysis of straying of late-fall chinook salmon using the same methodology described above. Beginning with broodyear 1993, requests have been made from Interagency Ecological Program, and the various participating agencies (NMFS, DFG, DWR, USFWS) for CNFH to provide late-fall chinook salmon for releases into the interior Delta (Georgianna Slough), and various downstream control sites (i.e., Ryde, Isleton, Courtland, Port Chicago). The release groups have been requested as surrogates for winter-run chinook salmon and to evaluate and model modifications to Delta operations as to their potential effects (positive/negative).

In this straying analysis, indices of straying were generated for the releases made into the Delta and other downstream locations. Delta and downstream release sites generated relatively large stray indices of 71.4%, 54.3%, and 84.7% for broodyears 1993 through 1995 respectively. For these broodyears, multiple release groups for both on-site and downstream/ Delta locations were made, making this analysis more telling and likely more powerful than the analysis conducted with fall chinook salmon (see below). These data suggest that between approximately 54 and 84% of adults resulting from groups of juvenile released into the Delta ended up in freshwater locations other than Battle Creek. Tagged adults from these release groups have in fact been noted in the American River at Nimbus Hatchery (Alan Baracco, DFG, Personal Communication).

During 1993 through 1995, approximately 839 CNFH-origin coded-wire tagged late-fall chinook salmon adults were recovered directly at the hatchery, while 32 were collected at the Keswick Dam fish trap in the upper Sacramento River. The recovery values suggest a stray rate of approximately 4%. However, as the Keswick Dam is now the terminus for adult migration in the Sacramento River, it was felt that 4% would be reflective of a minimum value, as not all "strays" would be accounted for at this location.

B. Klamath Trinity Basin

Current hatchery production for the Klamath-Trinity (KT) basin is released on-site from the two large hatcheries, Iron Gate Hatchery and Trinity River Hatchery. During the late 1970s off-site releases of hatchery produced fish were conducted to evaluate the effects of site of release on rates of return to the hatchery and the various fisheries. Report authors were unable to locate any records regarding decisions to begin or discontinue off-site releases from Iron Gate or Trinity River hatcheries.

Two separate studies (Hankin, 1985 and Reavis and Heubach, 1993) were conducted in the KT basin that examined chinook salmon straying rates. In both of these studies straying was defined as "total estimated hatchery coded-wire tag escapement that failed to return to the hatchery of origin". Thus, hatchery produced chinook that returned to their basin of origin but failed to return to either Iron Gate or Trinity River Hatcheries were considered strays. Note that this definition of straying differs from the definition used to develop the stray indices for CNFH discussed earlier.

Estimated salmon escapement within the KT basin is produced in two separate ways; Trinity River escapement is based on mark-recapture estimates based on fish tagged at weirs and recaptured at Trinity River Hatchery, while Klamath River estimates are primarily based on carcass counts. Thus, Trinity River CWT estimates are based on the percentage of CWT fish observed at the weir, while Klamath River CWT estimates are based on actual or expanded counts observed in censussed spawning grounds.

Hankin (1985) analyzed recoveries of chinook salmon CWT release groups from Iron Gate and Trinity River hatcheries for brood years 1976-1980 for survival and stray rates. Off-site releases of Trinity River fall chinook were included in the analysis. The principal findings regarding stray rates were the following:

1. Iron Gate Hatchery fall chinook tend to stray at a much lower rate than Trinity River Hatchery fall chinook. Trinity River Hatchery fish are regularly recovered at Iron Gate hatchery and in some years at the Cole Rivers Hatchery on the Rogue River. Iron Gate Hatchery fish rarely are recovered at the Trinity River Hatchery or outside the river system.

2. Average overall straying rates for fish released from Iron Gate Hatchery as fingerling and yearling chinook were 22% and 18% respectively, and 58%, 57% and 45% for on-site Trinity River Hatchery fall fingerling, yearling and yearling plus chinook releases.

3. Average overall straying rates for off-site Trinity River Hatchery fall chinook fingerling releases were far greater than for fingerling on-site releases: straying rates averaged 90% for three off-site release groups.

4. Out of basin straying was observed for Trinity River, primarily in Oregon and to a lessor degree Washington.

5. Release and recovery data for Iron Gate Hatchery chinook reared at off-site ponds was inconsistent and could not be analyzed in a useful manner.

Reavis and Heubach (1993) compared survival and homing tendency for tagged groups of fall-run chinook salmon reared at Trinity River Hatchery and stocked at several locations in the Trinity River. Paired groups of releases (same brood year and release type) for the 1977-84 brood years were performed using Trinity River Hatchery and downstream off-site releases. Homing tendency of the off-site release groups was compared to the Trinity River Hatchery release groups using observed recoveries of adults. The homing tendency rate was calculated using a ratio of return rate (Trinity River Hatchery returns) to the catch rate for each paired release group. The quotient of the two ratios (Trinity River Hatchery and off-site) is the estimated homing tendency for the group released downstream relative to the group released at the hatchery. A value of 1.00 indicates that the homing tendency of the group released downstream is the same as that of the group released from the hatchery; a value of 0.10 indicates that the group released downstream returns to Trinity River Hatchery at a rate of only 0.10 of the group released at Trinity River Hatchery.

The results of the paired release tests indicate that homing tendencies for off-site releases were considerably less than their Trinity River Hatchery released counterparts. Off-site releases of fall chinook fingerlings returned to the hatchery at a rate ranging from 0.07 to 0.56 as compared to Trinity River Hatchery releases. Furthermore, the distance of release from the hatchery and homing rates for the off-site release groups indicated that the further the release site was from the hatchery, the less likely those fish would return to the hatchery. Results of yearling release groups were similar, although homing rates improved, ranging from 0.48 to 0.74 as compared to their Trinity River Hatchery released counterparts.

The decision to experiment with off-site hatchery releases in the basin during the late 1970's and early 80's was in response to low returns at basin hatcheries and to the fisheries. The off-site release experiments, although somewhat successful for increasing contributions to the fisheries, were deemed too risky by DFG and the Klamath River Basin Fisheries Task Force when weighing the increased contribution rates versus the potential effects of genetic dilution and/or disease on natural stocks as a result of hatchery fish straying, and were therefore discontinued.

III. BENEFITS AND HAZARDS OF OFF-SITE RELEASES

A. Benefits

1. Increased Contribution to Ocean Harvest

Maximizing the potential of Central Valley hatchery salmon production is the prime motivation for the DFG's off-site release programs. Studies conducted with salmon from CNFH, Nimbus Hatchery (Hallock and Reisenbichler, 1979), Feather River Hatchery (Sholes and Hallock, 1979), and Mokelumne River Hatchery (Meyer, 1984) suggested that survival and subsequent contribution to the ocean fisheries could be increased by transporting and releasing fish in the western Delta. The studies used similar groups (in size of fish and number released) of marked (fin-clipped or coded-wire-tagged) hatchery fish released at the hatchery and downstream. Relative survival was determined through subsequent contribution of each group to the ocean fisheries and returns to the hatchery. Contribution (recovery) rates were calculated for each group as the observed number marked fish recovered at the hatchery (or the estimated number of marked fish recovered in ocean fisheries) divided by the number of marked fish released. During the 1970s, the furthest downstream planting location was primarily in the Sacramento River near Rio Vista. This site was replaced by the current release locations in the lower end of the estuary (Benicia) and San Pablo Bay (Vallejo and Rodeo) following studies of contribution rates from releases made in this environment (Meyer, 1986, 1987, 1994a, 1994b).

Table 3 summarizes recovery rates reported in three studies, and unreported data derived from DFG's coded-wire-tagging database. It includes those fall-run salmon releases replicated for a minimum of three brood years with recoveries through age 5-year-old. In all cases, estimation of ocean recoveries (sport and commercial fisheries) were based on data from fairly extensive sampling systems utilized by the Pacific coast states. Reported recoveries at the hatcheries were considered accurate since every fish is examined for marks.

Hallock and Reisenbichler (1979) reported a 157% increase in the contribution to ocean fisheries of fish released at Rio Vista compared to fish released at Nimbus, although the increase was not statistically significant ($p>10\%$). They also observed a significant ($p<5\%$) increase of 63% in returns to the hatchery of fish released at Rio Vista relative to hatchery released fish. CNFH chinook released at Rio Vista showed a 39% increase in contribution to ocean harvest but an 83% decrease in returns to the hatchery. Sholes and Hallock (1979) reported a 26% decrease in the ocean contribution rate of yearling chinook from the Feather River Hatchery released at Rio Vista and a 72% decrease in the returns to the hatchery, compared to fish released at the hatchery. Downstream releases of Mokelumne River Hatchery yearlings (Meyer,1984) resulted in ocean contribution rate over 2.5 times that of releases made at the hatchery, although there was a large drop in the return rate to the hatchery. Unpublished data from the DFG's CWT data base show substantial increases in both ocean contribution rate (1153%) and hatchery recoveries (259%) for Feather River Hatchery smolts released in the western Delta.

In each of five consecutive years, beginning in 1988, four groups of approximately 50,000 fall chinook salmon smolts from CNFH were released at Battle Creek, RBDD, Princeton, and Benicia. Rates of contribution to ocean fisheries were highly variable, depending on year and location of release, but followed generally similar trends within years for all release sites. Over the five years of investigation, fish released at Benicia contributed approximately three-fold more fish to the ocean fishery than releases at Battle Creek, RBDD, or Princeton. Average ocean fishery contribution rates were 0.310% for Battle Creek, 0.369 for RBDD, 0.318 for Princeton, and 0.947 for Benicia (USFWS, unpublished data). It should be noted that the differences in ocean contribution rates were observed during years of drought and below average flows in the Sacramento River. In 1988 when average daily flows in the Sacramento River were above average, ocean contribution rates were essentially equal between groups of fish released at the various locations.

In general, studies to measure the effects of down stream release on contribution rates to ocean fisheries (recoveries/number of fish released) suggest that the release of smolts in the western Delta improves the survival and subsequent contribution to ocean harvest relative to fish released at the hatchery. While off-site release may increase in ocean contribution rates by as much as 10 fold, the increase in survival does not necessarily result in increased returns to hatchery, presumably due to the increased straying of returning adults.

TABLE 3. Summary of Recovery Rates for Hatchery vs. Downstream Releases of Marked Fall-run Chinook Salmon.

Brood Year	Release Site Site	Avg.Wt. of fish (g)	Total No. Released	Ocean Recovery Rate 1/	Percent increase, Rio Vista compared to hatchery release	Source Hatchery Recovery Rate 2/	Percent increase, Rio Vista compared to hatchery release
1968 a/	Nimbus FH	5.9	250,265	0.12%	190%	0.028%	111%
	Rio Vista	5.7	252,904	0.33%		0.059%	
1969 a/	Nimbus FH	5.3	258,818	0.46%	318%	0.024%	229%
	Rio Vista	5.3	263,064	1.93%		0.079%	
1970 a/	Nimbus FH	5.6	258,278	0.73%	49%	0.085%	1%
	Rio Vista	3.8	257,213	1.08%		0.086%	
			TOTAL		**AVERAGE**		
Combined	**Nimbus FH**		**767,361**	**0.44%**	157%	**0.046%**	63%
	Rio Vista		**773,181**	**1.12%**		**0.075%**	
1968 a/	CNFH	6.4	294,834	0.38%	88%	0.060%	-73%
	Rio Vista	6.6	320,586	0.72%		0.016%	
1969 a/	CNFH	5.2	327,962	0.77%	10%	0.058%	-83%
	Rio Vista	4.6	327,265	0.84%		0.010%	
1970 a/	CNFH	5.5	371,672	0.61%	44%	0.055%	-91%
	Rio Vista	5.8	367,869	0.89%		0.005%	
			TOTAL		**AVERAGE**		
Combined	**CNFH**		**994,468**	**0.59%**	39%	**0.058%**	-83%
	Rio Vista		**1,015,420**	**0.82%**		**0.010%**	
1967 b/	Feather River FH	38.0	56,400	8.17%	-21%	0.817%	-56%
	Rio Vista	38.0	50,400	6.47%		0.357%	
1969 b/	Feather River FH	60.0	20,625	12.07%	-31%	0.508%	-97%
	Rio Vista	60.0	20,025	8.34%		0.015%	
1970 b/	Feather River FH	76.0	59,520	0.88%	0%	0.091%	-67%
	Rio Vista	76.0	59,820	0.87%		0.030%	
			TOTAL		**AVERAGE**		
Combined	**Feather River FH**		**136,545**	**7.11%**	-26%	**0.472%**	-72%
	Rio Vista		**130,245**	**5.23%**		**0.134%**	
1977 c/	Mokelumne River FI	57.0	44,287	1.15%	128%	0.063%	-86%
	Rio Vista	53.0	44,284	2.62%		0.009%	
1978 c/	Mokelumne River FI	68.0	38,739	2.18%	218%	0.289%	-91%
	Rio Vista	65.0	36,610	6.94%		0.025%	
1979 c/	Mokelumne River FI	93.0	39,137	0.53%	174%	0.059%	-85%
	Rio Vista	93.0	42,504	1.45%		0.009%	
			TOTAL		**AVERAGE**		
Combined	**Mokelumne River FI**		**122,163**	**1.29%**	184%	**0.137%**	-90%
	Rio Vista		**123,398**	**3.67%**		**0.014%**	
1978 d/	Feather River FH	4.5	181,028	0.01%	15120%	0.001%	1100%
	Port Chicago	7.4	110,122	0.76%		0.012%	
1979 d/	Feather River FH	8.3	176,851	0.45%	389%	0.094%	55%
	Port Chicago	8.8	168,143	2.18%		0.146%	
1980 d/	Feather River FH	8.1	178,831	0.01%	46050%	0.001%	18600%
	Rio Vista/Port Chicago	7.3	87,203	2.77%		0.187%	
			TOTAL		**AVERAGE**		
Combined	**Feather River FH**		**536,710**	**0.15%**	1153%	**0.032%**	259%
	Rio Vista/Port		**365,468**	**1.90%**		**0.115%**	

DATA SOURCE:
a/ Hallock & Reisenbichler, 1979.
b/ Sholes & Hallock,1979.
c/ Meyer, 1984.
d/ Unpublished data, DFG CWT-database.

1/ Number of estimated sport and commercial harvest recoveries for entire Pacific coast divided by number released.
2/Actual returns to hatchery of origin.

Releases of CNFH marked smolts from broodyears 1987 to 1991 were part of a site of release evaluation conducted in cooperation with the DFG. General conclusions from that report as well as the additional analysis demonstrate releases of fish west of the Delta result in higher ocean contribution rates and likely overall survival than upstream releases (USFWS, 2001)

2. Reduced competition and predation on local natural spawning populations

Salmon released as smolts (60-90 mm fork length) are unlikely to feed on natural origin salmonids (Petrusso, 1998; BPA 1997). However, significant predation may occur when yearling salmonids are released during the emergence of natural salmon (Steward and Bjornn 1990). Yearling chinook and steelhead have a greater potential for preying on newly emerged salmon fry due to their larger size, piscivorous feeding habits and, in the case of steelhead, a tendency to residualize to non-anadromous life history patterns. Sholes and Hallock (1979) estimated 500,000 yearling chinook salmon released in California's Feather River consumed 7,500,000 emergent chinook salmon and steelhead trout fry. Hallock (1989) reported sampling of stomach contents of steelhead yearlings released into Battle Creek in February and March 1975 revealed an average of 1.4 fall chinook salmon per steelhead stomach.

Competition for limited resources may occur when hatchery and natural origin salmon and steelhead overlap in time and space (Steward and Bjornn 1990, Cannamela 1992). Nickelson et al. (1986) and Nielsen (1994) reported that pre-smolt releases of hatchery-origin coho salmon were associated with displacement of natural coho from their usual territories.

The extent of competition and predation by hatchery origin salmon and steelhead on natural origin salmonids will depend on such factors as the presence of natural populations at the time of hatchery releases, the relative sizes of the hatchery and natural populations in relation to carrying capacity, the speed with which the hatchery fish emigrate to the ocean, and whether the hatchery fish are piscivorous at the time of release.

The effects of competition and predation may be reduced or eliminated by transporting hatchery fish to areas where competition and predation are less likely to occur. For example, steelhead from Nimbus Hatchery and CNFH are transported for release in the Sacramento River due to concerns regarding predation. The variable flows and turbidities in the Sacramento River during January and February may reduce the ability of steelhead to find and identify prey. Bigelow et al. (1995) found no evidence of piscivory in the stomach contents of 133 hatchery steelhead collected in the Sacramento River.

B. Hazards and Risks

A *hazard* is the adverse consequence of some action. *Risk* is the probability that a hazard will be realized. Artificial propagation creates many hazards for natual salmonid populations, and the increased straying caused by off-site release increases risk. It is important to remember that even if off-site release didn't increase straying *rate*, large release groups could generate large *numbers* of strays. In this section, we review the hazards posed by artificial propagation and how straying from hatchery populations increases risk. Hazards can be grouped into three categories: management hazards, ecological hazards and genetic hazards.

1. Ecological hazards

Straying by hatchery-origin fish could pose a variety of ecological hazards to natural populations, including competition for redd sites and redd superposition, reduced productivity of natural fish breeding with hatchery fish, and disease transmission. These ecological interactions can also have genetic consequences because they alter the selective regime of the natural fish (Waples, 1991).

Hatchery-origin fish spawning in the wild must compete with natural fish for spawning habitat, and their offspring must also compete for rearing habitat. Competition is probably most significant in streams with hatcheries (Battle Creek, Feather River, American River, Mokelumne River, Merced River), and in these cases, wild-spawning hatchery fish might only be considered strays because they have been denied access to their hatchery. In other streams, however, carrying capacities are generally unknown, and it is possible that all available habitat would be fully utilized by natural spawners and their progeny. In this case, hatchery strays would effectively reduce the carrying capacity for natural fish. Competition could be important at population levels below carrying capacity if fish compete for the best spawning and rearing habitats.

Aside from the genetic hazards discussed below, if hatchery fish have reduced or no fitness in the wild, then natural fish that breed with hatchery fish could have lower reproductive success than if they had bred with another natural fish. The results of Tallman and Healy (1994) suggest that this could be a real concern.

Straying could provide several ways for diseases to pass from hatchery fish to natural fish or from one watershed to another. For instance, there are some diseases that are endemic to the Central Valley. Central Valley fish have some level of immunity to these diseases, unlike fish from other basins. Straying of Central Valley hatchery fish into other basins has been observed, and these strays could bring diseases with them. Another possibility is transmission between natural and hatchery fish within a basin, either between adults on the spawning ground, or from carcasses to offspring which may feed on them.

2. Genetic hazards

The genetic hazards posed by hatchery programs have received much attention recently with the apparent collapse of many Pacific Northwest hatchery and natural stocks; see Waples (1991), Currens and Busack (1995), Busack and Currens (1995), Campton (1995), Grant (1997), and Utter (1998) for more detailed reviews. In this section, we summarize these papers.

Straying of hatchery fish into natural spawning areas directly poses two types of genetic hazards: 1) reduction of among-population genetic variation and 2) non-adaptive genetic changes within the hatchery that are then transferred to the natural populations causing reduced fitness.

Even if hatchery programs could avoid deleterious genetic changes within their hatchery stock, significant straying of hatchery fish to natural populations would result in gene flow from the hatchery to the natural populations. This gene flow can easily overwhelm the processes maintaining among-population genetic variation (e.g., drift, mutation, natural selection). Elevated straying can, over time, result in homogenization of populations; available evidence suggests that this already may have happened in the Central Valley fall chinook. Loss of among-population genetic variation has short- and long-term consequences. Among-population genetic variation is important for the long-term evolutionary potential of salmonids. Genetic variation is the raw material of natural selection, and salmonids will need it to adapt to natural and anthropogenic environmental change. NMFS considers within-ESU and among-population genetic diversity as one necessary component of viability for salmonid populations and ESUs (McElhany et al., 2000). One short-term consequence of homogenization is the loss of local adaptations and reduced productivity.

Elevated straying between genetically distinct populations can also cause outbreeding depression by disrupting gene complexes. Gene complexes are groups of linked alleles (i.e., they are close together on the same chromosome) that work together to produce phenotypes. These clusters can be disrupted by outbreeding, even when outbreeding is with fish of very similar phenotype. A compelling example of this is provided by the studies of Gharrett and coworkers (Gharrett and Smoker 1991, Gharrett et al. 1999) using cryopreserved gametes. In these studies, even- and odd-year pink salmon from the same stream (presumably the same selection regime) were crossed. As predicted by population genetic theory regarding gene complexes (Dobzhansky 1955, Emlen 1991), the first generation of offspring had similar survival as the parents, but their offspring had much reduced survival compared to non-outbred fish.

Another kind of outbreeding depression could result from hatchery fish breeding in the wild. Population genetic theory and some empirical studies show that artificial propagation causes rapid genetic changes in the hatchery stock. These changes come from two sources. First, hatcheries present a selective regime very different from the natural environment, which can result in domestication selection (Waples 1991, Busack and Currens 1995). Second, breeding practices and a relaxed selective regime can result in the accumulation of mutations that are selectively neutral in the hatchery but deleterious in the wild (M. Lynch, in preparation). For salmonids, empirical evidence for a loss of fitness due to artificial propagation comes from several studies, including those of Reisenbichler and McIntyre (1977), Reisenbichler (1997), and Reisenbichler and Rubin (1999), which show that stock productivity declines with increasing time with hatchery propagation. When domesticated or mutation-laden hatchery fish breed in the wild, nonadaptive alleles are transferred to the natural populations. If this gene flow is high, it can overcome natural selection which would otherwise remove these alleles from the natural population.

3. Management hazards

Effective management of California's natural salmonid resources requires reasonably accurate abundance estimates. Significant numbers of unmarked hatchery fish in natural spawning areas makes population assessment difficult if not impossible. Indeed, uncertainty about the contribution of hatchery-origin fish to fall-run chinook natural spawning populations was a major concern of the NMFS's BRT. Besides the ESA, the CVPIA AFRP mandates doubling of natural populations, which requires that natural populations be accurately enumerated– something that is quite difficult when many unmarked hatchery fish are present on the spawning grounds. A recent workshop on escapement estimation methodology (UC Davis, June 22, 2000) highlighted the fact that management of the Central Valley's salmonid resources is currently severely hindered by poor escapement estimates.

A major concern is that hatchery production and straying is masking declining productivity of natural populations. For instance, many Central Valley streams have roughly stable spawner counts over the past 20 years. Some fraction of these spawners (20-50%?) were born in a hatchery. This situation can be interpreted in several ways. One extreme is to assume that hatchery fish do not contribute to natural production, i.e., they are not reproductively successful. In this case, the natural fish productivity is enough to sustain the population, although the real natural population size is smaller than the apparent size. On the other extreme, one could assume that hatchery fish are as reproductively successful as natural fish. In this case, production is not self-sustaining, since without the hatchery production subsidy, the population would decline at a rate proportional to the fraction of fish that are of hatchery origin. In reality, the situation might lie somewhere between these extremes. Even if all hatchery production was marked, population assessment would still be difficult without detailed studies of reproductive success of hatchery-origin fish.

In the absence of accurate and precise population assessments, the risk of making wrong management decisions is high, and the consequences of these decisions could be serious. For instance, if one overestimates the production of natural populations by underestimating the contribution of hatchery strays to natural production, one might set harvest rates at levels that are unsustainable for many natural populations. Another product of highly uncertain population assessments is an inability to prioritize stocks for habitat restoration.

Another type of management hazard associated with off-site release is political. The NMFS is required by the ESA to protect natural populations and their ecosystems. It will be politically difficult to design and implement recovery plans for listed species, and will require broad public and stakeholder support. For may stakeholders, the presence of abundant salmon runs is important, but the origin of the runs is less important. These stakeholders would be more interested in habitat improvements required by natural spawners if their use of natural resources depended on the productivity of these natural runs. Off-site release programs may therefore reduce the political will and political capital required to save natural salmon runs.

C. A qualitative risk assessment

Managers should be most concerned about serious hazards with high risks of occurrence. From the above discussion, two hazards are outstanding by this standard. First, the management hazards posed by the masking effect are worrisome because this masking is definitely occurring, and the odds of making management mistakes because of this are quite high (in fact, the apparent poor status of many California chinook populations may be the result of failures in this area). On the other hand, these mistakes could be remedied if caught in time, and the masking problem could be solved with constant fractional marking of hatchery production (Hankin 1982, Hankin and Newman 1999) and careful genetic and behavior studies of naturally-spawning fish.

The genetic risks posed by artificial propagation are exacerbated by off-site releases and are a cause for serious concern. While the probability of genetic failure is unknown, in light of the problems in Oregon, Washington, and British Columbia hatcheries and the long time-frame of hatchery programs (longer than the lifespan of water development; Hilborn 1992), the risk may be quite high. Furthermore, the hazards are extremely serious, since they include extirpation of natural stocks and loss of significant genetic diversity, and not easily reversible in less than evolutionary time scales. In the Central Valley, fall chinook may already be largely homogenized, and spring chinook are threatened by strays from the Feather River Hatchery. Both spring- and fall-phenotype chinook at Feather River Hatchery can produce offspring with spring-run phenotype, and these fish could interbreed with Butte, Deer and Mill Creek spring chinook. The only way to minimize these risks is to minimize interactions between hatchery and natural stocks. The two obvious ways of reducing interaction would be reducing the numbers of returning hatchery fish (either through decreased production or selective harvest strategies), or by reducing the numbers of fish released off-site.

IV. CONCLUSIONS

1. Artificial propagation of salmon poses management, ecological, and genetic hazards to natural salmon populations. The risk of these hazards is increased by high rates of straying of hatchery populations.

2. Off-site release results in increased rates of straying of hatchery reared salmon relative to fish released on-site (at or near the hatchery). Published reports and the recent analysis of CNFH returns suggest that release in the lower estuary or San Francisco Bay results in stray rates exceeding 70%. Straying rates vary substantially among natural populations, and rate estimates vary depending on the definition of straying and study design. However, the available estimates of stray rates for hatchery populations released at the hatchery indicate that the increase in the rate of straying of fish released west of the Delta is substantial.

3. The mortality associated with transiting the Delta can be eliminated for hatchery fish by transporting and releasing production west of the Delta. As a result, transported fish may contribute to ocean fisheries at rates of three fold and higher compared to fish released upstream or at the hatchery.

4. In the Klamath Trinity Basin, experiments with off-site hatchery releases demonstrated some increased contribution rates to fisheries. However, in deciding whether to permanently implement off-site releases, the improved survival and resulting harvests did not seem to justify the potential negative effects of the increased rates of straying associated with the releases.

5. Water management practices within the Central Valley, including flow regimes below dams, temperature of reservoir releases, flow direction in some Delta channels and SWP/CVP exports in the south Delta, negatively affect juvenile salmonid emigration success and the ability of adults to home to natal streams.

V. RECOMMENDATIONS

1. The DFG should evaluate the genetic, management, and ecological risks associated with the substantial increase in straying of hatchery fish released off-site and weigh the risks against the benefits of increased survival and reduced interactions with naturally spawning stocks in waters adjacent to the hatchery. In certain cases the risks posed to natural populations appear to outweigh any benefits from increased contribution to fisheries. The review sub-committee recommends that the following off-site production releases in the Delta be considered for on-site release.

A. Feather River Hatchery spring chinook. The straying of Feather River Hatchery spring chinook poses hazards for the few remaining natural spring chinook runs in the upper Sacramento, which are listed under the state and federal endangered species acts.

B. Feather River Hatchery fall chinook. The fall chinook production is large and probably introgressed with the spring run. Straying of these fish may pose hazards to the long term productivity of naturally spawning fall-run populations in the Central Valley.

C. Nimbus Hatchery fall chinook. Straying of these fish may pose hazards to the long term productivity of naturally spawning fall-run populations in the Central Valley.

2. Hatchery releases and water management practices (including SWP/CVP exports) should be coordinated so that emigration survival is maximized. Flow patterns or poor water quality should not impede normal migration of adult salmon and steelhead or lead to lengthened or aborted migration pathways.

3. The DFG should continue the present policy of on-site release of salmon and steelhead produced in Klamath Trinity Basin hatcheries.

VI. RESEARCH NEEDS

1. Research should be continued to further understand the genetic structure and ecology of salmonid populations in California. Although some information is available regarding the genetic relationships among both hatchery and natural salmonid populations in California, expansion of this knowledge is necessary to better enable fishery managers to make informed decisions regarding fishery resources. In addition, better information regarding the life histories of hatchery and natural salmonids is also necessary for effective management.

2. Research should be conducted to further assess the interactions between natural and hatchery salmonids. As changes occur in hatchery operations and the aquatic environment, interactions between hatchery and natural salmonids may also change. The continued evaluation of hatchery programs is imperative for their effective management.

ANCILLARY INFORMATION ON KLAMATH TRINITY

Annual escapement estimates are generated for fall chinook within the basin and estimates for spring chinook, coho and steelhead are generated for the Trinity River. Estimating CWT recovery rates is a part of these tasks. This information is used for cohort analysis, part of the population modeling used to predict future abundance within the basin. These estimates are then used to partition harvest quotas to the various user groups.

Klamath basin escapement is determined from carcass, weir counts, and redd surveys. Major sub-basins such as the Scott, Shasta and Salmon rivers are censussed annually by the Department, Forest Service, Tribes, Fish and Wildlife service and volunteers. Weir counts are performed annually on Bogus Creek. Bogus Creek is located just downstream of Iron Gate Hatchery (IGH). Approximately 90% of chinook spawning occurs in the basin tributaries, the remaining 10% spawn in the mainstem. Very limited information exists for coho and steelhead numbers in the Klamath basin due to the difficulty in maintaining census operations under high flow conditions.

Based on CWT recoveries, IGH fall chinook display a high fidelity for the hatchery. The highest number of strays are encountered in Bogus Creek, while very few are recovered elsewhere, with the exception of the 1995 return year. During that year, the K-T basin experienced a very large (~220,000) return of fall chinook that overwhelmed IGH. The hatchery ladder was closed for a period of time that led to high stray rates that year. Subsequent to this, policy was changed to facilitate more consistent operations.

The Scott, Salmon, and Shasta River, various tributaries, and Bogus Creek sub-basins have been monitored annually for a number of years. Carcass and weir counts provide the best information within the basin for examining the incidence of straying in the Klamath Basin. Table 1 below summarizes sampling expansions of total CWT recoveries in these sub-basins and total recoveries at IGH. It should be noted that all CWTs are included here, regardless of origin and that this table should only be interpreted as a rough estimate for assessing straying. CWT groups released from Trinity River Hatchery (TRH), Trinity River wild, and several small ponding sites within the Klamath and Trinity basins have been recovered in some of these areas. However, the vast majority of CWT codes found are of IGH origin. Bogus Creek enters the mainstem Klamath in close proximity to IGH and the high rate of straying is expected.

Table 1. CWT recoveries in selected Klamath Basin sites.

Year	Salmon River	Scott River	Shasta River	Bogus Creek	Misc.Tribs	IGH
1999 a/	0	0	5	245	2	674
1998	0	0	0	153	0	1141
1997	2	2	0	29	0	471
1996	17	0	0	15	1	542
1995	3	19	66	590	87	1186
Totals:	22	21	71	1032	90	4014
% combined totals	0.42	0.40	1.4	19.7	1.7	76.5

a/ Preliminary data

Annual CWT recovery percentages for the 1995-99 return years for the above selected sites (Table 1), have ranged from a low of 5.7% (1996) to a high of 39.2% (1995), averaging 18.1% for sites other than IGH. These percentages should be considered minimums since mainstem spawning is estimated from redd surveys and recovery of carcasses has been minimal due to the difficulty in recovering these fish. It is assumed that some mainstem spawners, particularly those found in the upper Klamath near IGH, would be of hatchery origin.

Trinity Basin chinook, coho and steelhead escapements are estimated using mark-recapture methods. Temporary weirs are put into the river near the towns of Willow Creek (rkm 48.4) and Junction City (rkm 131.5). Fish are trapped and tagged at the weirs and later recovered at TRH (rkm 179.8). Estimates are made based on the number of marked fish times the ratio of unmarked to marked fish recovered at TRH. The Junction City weir (JCW) is used to make estimates for Spring-run chinook, while the Willow Creek weir (WCW) is used to make estimates of fall-run chinook, coho, and fall-run steelhead. Harvest rate estimates for these species are determined from the return of reward tags, which are placed on a percentage of fish at each weir. In contrast, Klamath basin estimates for fall chinook are based on carcass and redd counts. Klamath harvest estimates are based on creel census data.

The percentage of TRH marked fish (CWTs) in each year's run is determined by examining the percentage of marked fish at each weir for each species. This percentage is then multiplied by the overall run-size to produce a CWT run-size estimate. For example, if the fall run of chinook salmon was estimated at 50,000 fish and 10% of all fall chinook trapped at WCW were AD marked, then 5,000 would be the CWT estimate for that year and species. The overall CWT run-size is apportioned to the various hatchery release groups based on the percent composition of each group returning to TRH. All fish entering TRH are examined and counted, thus the difference between the CWT run-size estimate and the number of CWT's counted at TRH plus estimated in-river CWT harvest is the estimated number of CWT strays.

TRH produced fish display a moderate to high fidelity to return to the Trinity River, but not necessarily to the hatchery itself. Straying of TRH produced fish has been documented in the Klamath River and to several Oregon locations (Hankin 1985). Within the Trinity Basin, both races of chinook and coho salmon are estimated to stray at considerable rates. The term "stray" in this context is defined as the percent age of hatchery spawners that do not enter the hatchery upstream of the weir from which the estimate was developed. Annual estimated stray rates are presented in Table 2. These values are developed by the CDFG, Trinity River Project, for cohort reconstructions used in annual escapement projections by the Pacific Fishery Management Council (PFMC). Chinook release types (fingerling and yearling) are aggregated.

Table 2. Estimated Stray Rates for Trinity River Hatchery Produced Chinook and Coho Salmon.

Year	Spring Chinook a/	Fall Chinook b/	Coho b/
1999 c/	46.5%	49.6%	30.8%
1998	56.3%	44.9%	57.0%
1997	47.1%	40.3%	75.8%
1996	64.6%	70.3%	N/D d/
1995	N/D	75.0%	N/D
Mean Stray Rate:	53.6%	56.0%	54.5%

a/ Estimated stray rate above Junction City Weir. b/ Estimated stray rate above Willow Creek Weir. c/ Preliminary data. d/ N/D=No data. CWT estimates in Table 2 are based on overall run-size estimates which have differing levels of confidence intervals by year and species. Additionally, naturally produced chinook salmon were tagged for a number of years in the upper basin. Returns of these fish may have positively biased TRH CWT run-sizes. However, this table provides a good indication that significant straying within the Trinity Basin does occur.

AGENCY POLICIES/GUIDANCE REGARDING PRESERVATION OF GENETIC RESOURCES AND STRAYING OF HATCHERY POPULATIONS

National Marine Fisheries Service

The legislative history of the Endangered Species Act, which is intended to slow the current pace of species extinction, notes: “As we homogenized the habitats in which these plants and animals evolved, and as we increase the pressures for products that they are in a position to supply (usually unwillingly) we threaten their - and our own - genetic heritage. The value of this genetic heritage is quite literally incalculable. From the most narrow possible point of view, it is within the best interests of mankind to minimize the losses of genetic variations. The reason is simple: they are potential resources. They are keys to puzzles which we cannot solve, and may provide answers to questions which we have not yet learned to ask.” (H.R. Rep. No. 412)

“The major constraints governing the use of artificial propagation in ESA recovery programs should be the maintenance of genetic and ecological integrity and diversity in listed species. Artificial propagation of unlisted species should be conducted to minimize adverse impacts to listed and unlisted species. The liberation of large numbers of fish genetically distinct from natural fish and the impacts of mixed-stock fisheries associated with this enhancement may have profound consequences for the viability of some distinct populations, including loss of genetic integrity and ecological diversity, increased competition, and elevated levels of harvest and natural predation.” (Hard et al. 1992)

NMFS recent characterization of viable salmon population attributes (McElhany, P., et al. 2000) contains the following guidelines: Natural rates of straying among subpopulations should not be substantially increased or decreased by human actions. This guideline means that habitat patches should be close enough together to allow appropriate exchange of spawners and the expansion of the population into under-used patches, during times when salmon are abundant. Also, stray rates should not be much greater than pristine levels, because increases in stray rates may negatively affect a population’s viability if fish wander into unsuitable habitat or interbreed with genetically unrelated fish..

Natural processes of dispersal should be maintained. Human-cased factors should not substantially alter the rate of gene flow among populations. Human caused inter-ESU stray rates that are expected to produce (inferred) sustained gene flow rates greater than 1% (into a population) should be cause for concern. Human caused intra-ESU stray rates that are expected to produce substantial changes in patterns of gene flow should be avoided.

In July 2000, NMFS adopted a rule under section 4(d) of the ESA prohibiting the "take" of 14 groups of salmon and steelhead listed as threatened ESA. This rule prohibits anyone from taking a listed salmon or steelhead, except in cases where the take is associated with an approved program. It provides a way to permit the "take" of listed fish for a variety of hatchery purposes through the development of a Hatchery and Genetics Management Plan (HGMP). Among other things, the HGMP must evaluate and minimize the genetic and ecological effects of propagation programs on natural populations, including disease transfer, competition, predation and genetic introgression caused by straying of hatchery fish.

California Department of Fish and Game

Current direction for the California Department of Fish Game regarding salmonid genetic resources are provided by Fish and Game Commission policies, Department management policies, and hatchery guidelines (goals and constraints). It is the policy of the Fish and Game Commission that the populations and genetic integrity of all identifiable stocks of salmon and steelhead rainbow trout be maintained, with management emphasis placed on natural stocks. The Department's Salmon and Steelhead Stock Management Policy focuses on the Commission's stand to protect the genetic integrity of stocks, through evaluation of salmon or steelhead streams and classification of their stocks according to probable genetic source and degree of integrity. Management and restoration efforts, and the role of artificial production are guided by this classification system.

The objective of the Department's hatchery system to maintain genetic integrity of local stocks is accomplished through limitation of interbasin transfer of eggs or fish and development of mating protocols, appropriate to each facility. Guidance on, or limitations of, straying by hatchery-produced salmonids is not specifically provided by state policies. It is a general objective of hatchery operations to minimize interactions between artificially- and naturally-produced fish. However, this goal is primarily intended toward interactions of juveniles (e.g. competition, predation) rather than returning adults.

Oregon

Operating Principles for Wild Fish Management (Division 7 Oregon Administrative Rules, Fish Management and Hatchery Operation Effective June 1, 1992)

Interbreeding of hatchery and wild fish: The interbreeding of hatchery fish with wild fish of the same taxonomic species poses risks to conserving and utilizing the genetic resources of wild populations. To reduce this risk, naturally spawning hatchery fish, whether originating from on-site releases or from strays from other release sites, shall be limited by both number in the natural spawning population and genetic characteristics. Options consistent with these rules are:

(a) Release no hatchery fish;

(b) Release hatchery fish that meet the following minimum standards and limit the number of hatchery fish in the naturally spawning population to 50% or less of the breeding population:

(A) Originates from wild fish belonging to the population specified by the statewide wild population list (OAR 635-070529(3)) for the geographic location under consideration;
(B) After broodstock is initiated, incorporates at least 30% wild fish on the average every brood year;
(C) Twenty-five percent or less of the wild donor population is taken for hatchery brood stock in any year;
(D) No intentional artificial genetic changes occur; unintentional artificial changes are avoided;
(E) Wild-type phenotypes are maintained in hatchery fish;

(F) The hatchery program shall be monitored annually and evaluated every 10 brood years to determine if the standards in paragraphs (A) through (E) are being met. If the standards are not being met, the number of hatchery fish spawning in the natural population shall be decreased as directed in subsection (c) of this section.

(c) Release hatchery fish, but limit the number of hatchery fish spawning in the natural population such that the further the deviation from the requirements of subsection (b) of this section the lower the proportion of hatchery fish that shall be allowed to spawn in the natural population consistent with current Department guidelines. Hatchery fish that do not at least meet the standards in paragraphs (A) and (C) in subsection (b) of this section shall be restricted to less than 10% of the naturally spawning population.

Wild Fish Gene Resource Conservation Policy: Wild fish shall be managed to maintain their adaptiveness and genetic diversity. These characteristics are important for maintaining the evolutionary potential of populations and preventing the serious depletion of these species in natural ecosystems. The Department recognizes and accepts that genetic changes will occur as part of the natural evolutionary process.

Hatchery Fish Gene Resource Management Policy: Hatchery fish populations shall be managed to maintain genetic diversity, to assure that the populations meet the management objectives for which they are produced, and to maintain their optimum biological and economic value.

Washington

Guidance Regarding Allowable Gene Flow: Genetic diversity within and among stocks will be maintained or increased to encourage local adaptation and sustain and maximize long-term productivity. Conditions will be created that allow natural patterns of genetic diversity and local adaptation to occur and evolve. Human caused gene flow between species, major ancestral lineages, genetic diversity units, or stocks through direct transfer of fish across stock or other boundaries should not be allowed. This will require the development of local broodstocks for many hatchery and other enhancement programs. Where there is no supplementation program in place, the allowable percentage of the total wild spawning population that is made up of fish raised in a hatchery is given in Table 1. For supplementation programs of hatchery-origin fish, proportions of hatchery fish will be decided on a case-by-case basis. These percentages of hatchery fish in Table 1 are surrogates for and are equal to allowable gene flow. Other measures of potential gene flow may be used (e.g., migrants per generation), if they result in similar levels of potential gene flow. Where treaty fisheries are affected, the Department shall address gene flow within the brood stock planning framework with affected tribes.

Table 1. Allowable Percentages of Hatchery Fish on the Spawning Grounds.

Level of Similarity of Hatchery Fish	Maximum % of Wild Spawning Population that is of Hatchery Origin
High	5-10%
Intermediate	1-5%
Low	0-1%

This policy uses the stricter definition of similarity that compares the hatchery fish with an ideal locally adapted wild fish. This maintains a higher level of local adaptation in populations that are already locally adapted, and increases the rate at which a hatchery influenced wild population becomes locally adapted. Similarity is determined based on the geographical origin, hatchery history, and hatchery practices that have affected the hatchery fish. In a hatchery population with high similarity, the hatchery fish will be of local wild stock origin and have few generations in the hatchery. There will be regular introductions of new wild broodstock into the hatchery population and the hatchery rearing conditions will be similar to wild conditions. Time spent in the hatchery will be limited and strict spawning guidelines will be followed. A highly similar stock will need to pass all these tests. A low similarity hatchery population will have many generations in the hatchery. There may have been selection for timing or size and the population may have been at very low numbers at times. There are few introductions of wild fish or it may have been started with non-local fish. A low similarity stock will have to meet only one of these criteria. Intermediate stocks exceed all the low criteria, but fail to meet at least one of the high criteria. Most current hatchery populations will be either low or medium similarity.

Hatchery fish spawning in the wild shall be controlled and limited so that the majority of stocks in a major watershed, river basin, or GDU do not have any hatchery gene flow, and so that the higher maximum percentages of hatchery fish on the wild spawning grounds noted are exceptions (i.e., occur infrequently and not in the most abundant or most unique components of the larger population groupings).

Department staff shall emphasize use of broodstock in fish culture operations that are locally adapted and highly similar to the wild stocks in that area. In some cases, however, it is better to use broodstocks that have been selectively bred or are adapted to cultured conditions. Such existing programs are the rainbow trout strains used for the stocking of lakes and the use of early-time returning winter steelhead. Using hatchery adapted fish where gene flow and ecological interactions with wild stocks can be controlled (is essentially zero) is a recognized and valid management tool. (from WDFW website - Additional Policy Guidance on Deferred Issues Concerning Wild Salmonid Policy, Adopted by Washington Fish and Wildlife Commission December 5, 1997)

REFERENCES

Adkison, M. A. 1995. Population differentiation in Pacific salmon: local adaptation, genetic drift, or the environment? Can. J. Fish. Aquat. Sci. 52:2762–2777.

Bams, R. A. 1976. Survival and propensity for homing as affected by presence or absence of locally adapted paternal genes in two transplanted populations of pink salmon (Oncorhynchus gorbuscha). J. Fish. Res. Board Can. 33:2716-2725.

Banks, M.A., V.K. Rashbrook, M.J. Calavetta, C.A. Dean, and D. Hedgecock. 2000. Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon (Oncorhynchus tshawytscha) in California's Central Valley. Can. J. Fish. Aquat. Sci. 57:915–927.

Bartley, D. M. and G. A. E. Gall. 1990. Genetic structure and gene flow in chinook salmon populations of California. Trans. Am. Fish. Soc. 119:55–71.

Bigelow, J.P., K. Brown, and S. Hamelberg. 1995. Hood habits of steelhead trout smolts released from Coleman National Fish Hatchery in the upper Sacramento River, California. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office, Red Bluff, California 10-42.

Boydstun, L.B., R. Hallock, and T.J. Mills. 1992. Salmon. In California's Living Marine Resources and their Utilization. W. Leet, C. Dewees and C. Haugen, eds., California Sea Grant, UCSGEP-92-12.

BPA (Bonneville Power Administration). 1997. Final environmental impact statement Nez Perce tribal hatchery program. Prepared by Bonneville Power Administration, U.S. Department of Energy, Bureau of Indian Affairs, U.S. Department of the Interior and Nez Perce Tribe. July 1997.

Busack, C.A. and K.P. Currens. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. In Uses and effects of cultured fishes in aquatic ecosystems, J. H. L. Schramm and R. G. Piper, eds., vol. American Fisheries Society Symposium 15, pp. 71–80. American Fisheries Society, Bethesda, MD.

California Department of Fish and Game (DFG). Annual Report Trinity River Basin Salmon and Steelhead Monitoring Project.

California Department of Fish and Game (DFG). 1998. A status review of the spring-run chinook salmon (Oncorhynchus tshawytscha) in the Sacramento River drainage. Candidate Species status report 98-01

California Department of Fish and Game (DFG). 1996 Hatchery Goals and Constraints. Iron Gate and Trinity River Hatchery Operational Goals and constraints.

Campton, D.E. 1995. Genetic effects of hatchery fish on wild populations of Pacific salmon and steelhead: what do we really know? In Uses and effects of cultured fishes in aquatic ecosystems, J. H. L. Schramm and R. G. Piper, eds., vol. American Fisheries Society Symposium 15, pp. 337–353. American Fisheries Society, Bethesda, MD.

Cannamela, D.A. 1992. Potential impacts of releases of hatchery steelhead trout smolts on wild and natural juvenile chinook and sockeye salmon. A White Paper. Idaho Department of Fish and Game, Eagle, Idaho.

Chadwick, H.K. 1982. Biological effects of water projects on the Sacramento-San Joaquin estuary. pp. 215-219 In: W. Kockelman, T. Conomos, and A. Leviton, eds. San Francisco Bay: use and protection. Amer. Assoc. for the Advancement of Science, Pac. Div.

Cramer, S.P. 1989. Contribution of Sacramento Basin hatcheries to ocean catch and river escapement of fall chinook salmon, pp. 113. Gresham, OR: S. P. Cramer and Associates, Inc.

Currens, K.P., and C.A. Busack. 1995. A framework for assessing genetic vulnerability. Fisheries (Bethesda) 20:24-31.

Dettman, D.H. and D.W. Kelley. 1987. The roles of Feather and Nimbus salmon and steelhead hatcheries and natural reproduction in supporting fall run chinook salmon populations in the Sacramento River Basin. D.W. Kelley & Associates. 8955 Langs Hill Road, Newcastle, CA.

Dittman, A.H., T.P. Quinn, and G. A. Nevitt. 1996. Timing of imprinting to natural and artificial odors by coho salmon (Oncorhynchus kisutch). Can. J. Fish. Aquat. Sci. 53:434-442.

Dizon, A.E., B.L. Taylor, and G.M. O'Corry-Crowe. 1995. Why statistical power is necessary to link analyses of molecular variation to decisions about population structure. In Evoluation and the aquatic ecosystem, J. L. Nielsen and D. A. Powers, eds., vol. American Fisheries Society Symposium 17, pp. 288–294. American Fisheries Society, Bethesda, MD.

Dobzhansky, T. 1955. Genetics of the evolutionary process. Columbia University Press.

Emlen, J.M. 1991. Heterosis and outbreeding depression: a multilocus model and an application to salmon production. Fish. Res. 12:187–212.

Foerster, R.E. 1968 The sockeye salmon, Oncorhynchus nerka. Bulletin of the Fisheries Research Board of Canada 162, 422.

Gall, G.A.E., D. Bartley, B. Bentley, J. Brodziak, R. Gomulkiewicz, and M. Mangel. 1991. Geographic variation in population genetic structure of chinook salmon from California and Oregon. Fish. Bull, U.S. 90:77–100.

Gharrett, A.J. and W.W. Smoker. 1991. Two generations of hybrids between even-and odd-year pink salmon (Oncorhynchus gorbuscha): a test for outbreeding depression? Can. J. Fish. Aquat. Sci. 48:1744–1749.

Gharrett, A J., W.W. Smoker, R.R. Reisenbichler, and S.G. Taylor. 1999. Outbreeding depression in hybrids between odd- and even-broodyear pink salmon. Aquaculture 173:117–129.

Giger, R.D. 1972 Ecology and management of coastal cutthroat trout in Oregon, pp. 61. Corvallis: Oregon State Game Commission.

Grant, W.S. (editor). 1997. Genetic effects of straying of non-native fish hatchery fish into natural populations: proceedings of the workshop. U.S. Dep. Commer., NOAA Tech Memo. NMFS-NWFSC-30, 130p.

H.R. Rep. No. 412, 93d Cong., 1st Sess. 4-5 (1973)

Hallock, R.J. 1980. Returns from Coleman Hatchery Steelhead Trout, Salmo gairdnerii, Released at the Hatchery and at Rio Vista. Anadromous Fisheries Branch Office Report. Oct. 15, 1980. 4pp.

Hallock, R.J. 1989. Upper Sacramento River steelhead, Oncorhynchus mykiss, 1952-1988. Report to U.S. Fish and Wildlife Service. 86 pp.

Hallock, R.J., and R.R. Reisenbichler. 1979. Evaluations of Returns from Chinook Salmon, Oncorhynchus tshawytscha, Released as Fingerlings at Coleman and Nimbus Hatcheries and in the Sacramento River Estuary. Anadromous Fisheries Branch Office Report. Aug. 22, 1979. 10pp.

Hankin, D,G. 1982. Estimating escapement of Pacific salmon: marking practices to discriminate wild and hatchery fish. Trans. Am. Fish. Soc. 111:286-298

Hankin, D.G. 1985. Analysis Of Recovery Data For Marked Chinook Salmon Released From Iron Gate and Trinity River Hatcheries, And Their Implications For Management Of Wild And Hatchery Stocks In The Klamath River System. BIA Contract # 100-FISH-513.

Hankin, D.G., and K. Newman. 1999. Improved methods for assessment of the contribution of hatcheries to production of chinook salmon and seelhead in the Klamath Trinity river system. Contract report, Hoopa Valley Tribal Fisheries Department, Hoopa, CA.

Hard, J.J., Jones, J., Delarm, M.R., and Waples, R.S. 1992 Pacific Salmon and Artificial Propagation Under the Endangered Species Act. NOAA Technical Memorandum NMFS-NWFSC-2

Hard, J.J. and W.R. Heard. 1999. Analysis of straying variation in Alaskan hatchery chinook salmon (Oncorhynchus tshwaytscha) following transplantation. Can. J. Fish. Aquat. Sci. 56:578–589. 2

Hilborn, R. 1992. Hatcheries and the future of salmon in the northwest. Fisheries 17:5–8.

Kim, T.J., K.M. Parker and P.W. Hedrick. 1999. Major histocompatibility complex differentiation in Sacramento River chinook salmon. Genetics 151:1115–1122.

Labelle, M. 1992 Straying patterns of coho salmon (Oncorhynchus kisutch) stocks from southeast Vancouver Island, British Columbia. Can. J. Fish. Aquat. Sci. 49, 1843-1855.

Mayr, E. 1966. Animal Species and Evolution. Harvard University Press. 795 p.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42, 158 p.

McIsaac, D.O., and T.P. Quinn. 1988. Evidence for a hereditary component in homing behavior of chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 45:2201-2205.

McIsaac, D.O. 1990 Factors affecting the abundance of 1977-1979 brook wild fall chinook salmon (Oncorhynchus tshawytscha) in the Lewis River, Washington. Seattle: University of Washington.

McQuarrie, D.W. & Bailey, D.D. 1980 Adult returns to Thornton Creek. In Proceedings of the 31st Annual Northwest Fish Culture Conference, pp. 36-44. Courtenay, B. C.

Meyer, F. 1984. Mokelumne River Fish Installation Versus Rio Vista: A Comparison of Yearling Chinook Salmon Releases. Anadromous Fisheries Branch Administrative Report No. 84-09. 8pp.

Meyer, F. 1986. Final Report, MRFI Yearling Chinook, Rio Vista vs Vallejo. Memorandum. Region 2 Files. May 28, 1986. 6pp.

Meyer, F. 1987. Final Report, Study of Pen-rearing Chinook Salmon at Tiburon. Memorandum. Region 2 Files. Dec. 9, 1987. 7pp.

Meyer, F. 1994a. Final Report - Mokelumne River Fish Installation, Coded-wire Tag Studies of Chinook Salmon Fingerlings. Memorandum. Region 2 Files. Feb. 7, 1994. 6pp.

Meyer, F. 1994b. Final Report, Fall-run Chinook Salmon, Planting Location and Day Versus Night Planting Studies. Memorandum. Region 2 Files. June 24, 1994. 5pp.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

Milner, A.M., and R.G. Bailey. 1989. Salmonid colonization of new streams in Glacier Bay National Park, Alaska. Aquacult. Fish. Manage. 20:179-192.

Nickelson, T.E., M.F. Solazzi, and S.L. Johnson. 1986. Use of hatchery coho salmon (Oncorhynchus kisutch) presmolts to rebuild wild populations in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 43:2443-2449.

Nielsen, J.L. 1994. Invasive cohorts—introductions of hatchery-reared coho salmon (Oncorhynchus kisutch): their impacts on the trophic, developmental and genetic ecology of wild stocks. Pp. 361-385 in D.J. Stouder, K.L. Fresh, and R.J. Feller (eds.), Theory and Application in Fish Feeding Ecology. Belle W. Baruch Library in Marine Sciences. University of South Carolina Press, Columbia, SC.

Nielsen, J.L., C. Gan, and W.K. Thomas. 1994a. Differences in genetic diversity for mitochondrial DNA between hatchery and wild populations of Oncorhynchus. Can. J. Fish. Aquat. Sci. 51:290–297.

Nielsen, J.L., D. Tupper, and W.K. Thomas. 1994b. Mitochondrial DNA polymorphisms in unique runs of chinook salmon Oncorhynchus tshawytscha from the Sacramento-San Joaquin River basin. Cons. Biol. 8:882–884.

Petrusso, P.A. 1998. Feeding habits and condition of juvenile chinook in the upper Sacramento River, California. Masters Thesis. Michigan State University, Department of Fisheries and Wildlife. 1998.

Quinn, T.P. 1984. Homing and straying in Pacific salmon. In: J. D. McCleave, G. P. Arnold, J.J. Dodson, and W.H. Neill (editors), Mechanisms of migration in fishes, p. 357-362. Plenum Press, NY.

Quinn, T.P. 1985. Homing and the evolution of sockeye salmon (Oncorhynchus nerka). Contrib. Mar. Sci. (Suppl.) 27:353-366.

Quinn, T.P. 1993. A review of homing and straying of wild and hatchery-produced salmon. Fisheries Research 18, 29-44.

Quinn, T.P. and K. Fresh. 1984. Homing and straying in chinook salmon (Oncorhynchus tshawytscha) from Cowlitz River hatchery, Washington. Can. J. Fish. Aquat. Sci. 41, 1078-1082.

Quinn, T.P., Nemeth, R.S. & McIsaac, D.O. 1991. Homing and straying patterns of fall chinook salmon in the lower Columbia River. Transactions of the American Fisheries Society 120, 150-156.

Reavis, R. and B. Heuback. 1993. Comparisons Of Survival And Homing Tendency For Tagged Groups Of Fall-Run Chinook Salmon (Oncorhynchus tshawytscha), Reared At Trinity River Hatchery And Stocked At Several Locations In The Trinity River With Estimates Of Contribution To Fisheries And Spawner Escapements. California Department of Fish and Game. Inland Fisheries Administrative Report No. 93-11.

Reisenbichler, R.R. and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, Salmo gairdneri. J. Fish. res. Board. Can. 34:123–128.

Reisenbichler, R.R. 1988. Relation between distance transferred from natal stream and recovery rate for hatchery coho salmon. N. Am. J. Fish. Manage. 8:172-174.

Reisenbichler, R.R. 1997. Genetic factors contributing to declines of anadromous salmonids in the Pacific Northwest. Pages 223-244 in D.J. Stouder, P.A. Bisson, and R. J. Naiman [eds.] Pacific Salmon and Their Ecosystems: Status and Future Options. Chapman & Hall, Inc., N.Y.

Reisenbichler, R.R. and S.P. Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES J. Mar. Sci. 56:459–466.

Ricker, W.E. 1972. Heredity and environmental factors affecting certain salmonid populations. In R. C. Simon and P. A. Larkin (editors), The stock concept in Pacific salmon, p. 19-160. N. R. MacMillan Lectures in Fisheries. Univ. British Columbia, Vancouver, B.C.

Sakano, E. 1960. Results from marking experiments on young chum salmon in Hokkaido, 1951-1959. Sci. Rep. Hokkaido Salmon Hatch 915:17-38. [In Jpn., Engl. summ.]

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. In California Department of Fish and Game Fisheries Bulletin, vol. 98, pp. 375.

Sholes, W.H. and R.J. Hallock. 1979. An Evaluation of Rearing Fall-run Chinook Salmon, Oncorhynchus tshawytscha, to Yearlings at Feather River Hatchery, With a Comparison of Returns from Hatchery and Downstream Releases. California Fish and Game 65(4): 239-255.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature. Part 2 in Miller, W.H. (ed.), Analysis of salmon and steelhead supplementation. Report to Bonneville Power Administration, Portland, OR. Tech. Rep. No. 90-1.

Tallman, R.F. and M.C. Healey. 1994. Homing, straying, and gene flow among seasonally separated populations of chum salmon (Oncorhynchus keta). Can. J. Fish. Aquat. Sci. 51:577–588.

Taylor, E.B., and J.D. McPhail. 1985. Variation in burst and prolonged swimming performance among British Columbia populations of coho salmon (Oncorhynchus kisutch). Can. J. Fish. Aquat. Sci. 42:2029-2033.

U.S. Fish and Wildlife Service (USFWS). 2001. Biological Assessment of artificial propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: program description and incidental take of chinook salmon and steelhead trout. USFWS, Red Bluf Fish and Wildlife Office, Red Bluff, CA.

Utter, F. 1998. Genetic problems of hatchery-reared progeny released into the wild, and how to deal with them. Bull. Mar. Sci. 62:623–640.

Utter, F., G. Milner, G. Stahl, and D. Teel. 1989. Genetic population structure of chinook salmon, Oncorhynchus tshwaytscha, in the Pacific Northwest. Fish. Bull., U.S. 87:239–264. 3

Vanderhaegen, G. and D. Dotty. 1995. Homing of coho and fall chinook salmon in Washington, pp. 68. Olympia: Washington Department of Fish and Wildlife.

Vreeland, R.R., R.J. Wahle, and A.H. Arp. 1975. Homing behavior and contribution to Columbia River fisheries of marked coho salmon released at two locations. Fish. Bull., U.S. 73:717-725.

Waples, R.S. 1991. Pacific salmon, Oncorhynchus spp., and the definition of "species" under the Endangered Species Act. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 53(3):11-22.

APPENDIX II. Klamath-Trinity Subcommittee Report.

Report of the Klamath Trinity Basin Hatchery Review Subcommittee
December 18, 2000

Trust Obligations to the Tribes

The Hoopa Valley and Yurok Indian Tribes (Tribes) possess a federally reserved right to harvest Klamath Trinity Basin fishery resources in an amount sufficient to support a moderate standard of living, up to 50% of the available harvest (DOI 1993). Klamath Trinity basin fishery resources include the production of Iron Gate and Trinity River Hatcheries, which mitigate for salmon production lost from the construction of dams on the Trinity and Klamath Rivers. The sub-committee affirmed that hatchery fish are a critical component of tribal fisheries, that the Tribes have a stake in hatchery operations and their participation in the California Department of Fish and Game (DFG)/National Marine Fisheries Service (NMFS) review of hatchery operations in the Klamath Trinity Basin is vitally important.

From a federal perspective, NMFS has both responsibility for administering the Endangered Species Act (ESA), and a federal trust responsibility to Indian tribes. In 1997 the Secretaries of the Departments of the Interior and Commerce issued an Order clarifying federal responsibilities when implementation of the ESA affects Tribal trust resources or exercise of treaty rights. The Order provides that tribes will not bear a disproportionate burden for conservation of listed species. Before Indian fishing rights may be constrained, it must be demonstrated that the conservation purposes of the contemplated restriction can not be achieved through the reasonable regulation of non-Indian activities. A 1998 letter from the Assistant Secretary of NOAA states that tribes may expect as a matter of policy that tribal fishing rights will be given priority over the interests of other federal and non-federal entities. These principles will apply to any actions that NMFS might consider with respect to hatchery operations in the Klamath Trinity Basin and their impact on ESA-listed species.

ESA Status of Klamath Trinity Basin Salmon Stocks

Klamath Mountains Province Steelhead - Not warranted for listing. The ESU includes steelhead from the Elk River in Oregon to the Klamath and Trinity Rivers in California, inclusive.

Southern Oregon/Northern California Coho - This Evolutionarily Significant Unit (ESU) is listed as threatened and consists of all naturally spawned populations of coho and their progeny that are part of the biological ESU and reside below long-term, naturally impassible barriers in streams between Punta Gorda and Cape Blanco. Hatchery populations from the Mattole, Eel, and Trinity Rivers and Rowdy Creek are considered part of the ESU (Mad River coho were not in the ESU, Iron Gate Hatchery (IGH) coho were of uncertain relationship to the ESU). None of the hatchery stocks in the ESU are considered “essential” for its recovery, and are therefore not listed. NMFS determined that two of the hatchery populations may play an important role in recovery efforts: Mattole River, because the natural population is very depressed, and the Trinity River, because there appears to be essentially no natural production in the basin. It is important to note that the determination that a hatchery stock is not ``essential'' for recovery does not preclude it from playing a role in recovery. Any hatchery population that is part of the ESU is available for use in recovery if conditions warrant. In this context, an ``essential'' hatchery population is one that is vital to fully incorporate into recovery efforts (for example, if the associated natural population(s) were extinct or at high risk of extinction). Under these circumstances, NMFS would consider taking the administrative action of listing the existing hatchery fish.

Upper Klamath-Trinity Chinook - Not warranted for listing. Includes all Klamath River Basin populations from the Trinity River and the Klamath River upstream from the confluence of the Trinity River. These populations include both spring- and fall-run fish that enter the Upper Klamath River Basin from March through July and July through October and spawn from late August through September and September through early January, respectively.

Southern Oregon and Northern California Coastal Chinook - Not warranted for listing. Includes streams from Euchre Creek, OR, through the Lower Klamath River (inclusive).

Production Levels

The subcommittee discussed the appropriateness of current hatchery coho production goals - how the goals were originally developed; whether mitigation was intended to replace a certain number of returning spawners, a certain number of outmigrants, or some amount of total adult production (ocean harvest + river harvest + spawning escapement); and whether production goals had been adjusted in consideration of the prohibition of coho retention in ocean and in-river sport fisheries. Because there appears to be essentially no natural production of coho in the Trinity River, the hatchery stock of coho produced at Trinity River Hatchery (TRH) will likely play an important role in recovery of naturally spawning populations.

Recommendation: The subcommittee recommends that a process be identified for the periodic (on the order of 6-9 years) review of hatchery production levels that would assess production at TRH and IGH in light of any of the following: 1) changes in ocean or freshwater harvest regimes; 2) new information on the effects of hatchery operations on natural populations; 3) changes in ESA status of Klamath Basin salmon and steelhead populations; and 4) changes to mitigation goals resulting from the upcoming Federal Energy Regulatory Commission's (FERC) relicensing process for Klamath Basin hydro-electric facilities. The process would include the DFG, agencies responsible for mitigating of salmon production, the Tribes, and NMFS (if ESA issues were applicable). As recovery efforts proceed under the ESA, the Tribes, DFG, and NMFS will need to determine how the coho program at IGH and TRH should best be utilized in the recovery of Klamath-Trinity Basin coho.

Time of Release

Iron Gate Hatchery Release Strategies

Several sub-committee members expressed concern regarding the current release strategy of fall chinook from IGH. The current operational goals and constraints document for IGH stipulate the volitional release of 4.9 million chinook salmon smolts when the average size of the entire production reaches 90 per pound with a release date window of June 1 - 15; and 1.08 million yearlings between October 15 – November 15. The June release is not a true volitional release because of the short release period; hatchery personnel crowd the fish out of the production ponds a few days after the pond screens have been removed. This procedure is often necessary to avoid the effects of increasing temperatures and decreasing water flows that typically occur in the river during June. The reduced flows minimize the amount of habitat available in the river, which increases the likelihood of competition between hatchery fish and the natural coho salmon (listed as "threatened" under the ESA), chinook salmon, and steelhead that are residing in the river. Reduced flow often results in poor water quality in the river, such as warm water temperature and low dissolved oxygen levels. This poor water quality results in extreme fish densities at areas of cold water refugia, such as the confluences of cold water tributaries.

The consequences of these poor water quality conditions were evident during the latter part of June, 2000, when temperatures in the mainstem Klamath River were in excess of 24EC and a substantial “fish kill” occurred. Several factors may have contributed to the poor water quality conditions following the release of 4.9 million smolts from IGH on June 9 and 10, 2000, such as: 1) the Bureau of Reclamation reduced flows in the mainstem Klamath to near 1,000 cfs on June 20, 2) unseasonably high air temperatures during the spring and early summer of 2000, and 3) reduced thermal refugia areas from tributaries because of the high air temperatures and diminished or depleted snow packs. Field crews that were monitoring the fish die-off noted high densities of fish located at the confluence of cold-water tributaries, with few live fish seen between these areas of cold water refuge. The densities of fish at these locations were likely exacerbated by the large number of hatchery smolts in the river. Densities of this magnitude are likely detrimental to natural fish populations by increasing stress (to fish already stressed from poor water quality), increasing competition for food and space, and increasing the likelihood of disease transmission between fish.

The subcommittee discussed two potential release strategies that may alleviate negative interactions between hatchery and natural fish following the release of IGH chinook smolts: 1) volitionally releasing a portion of the hatchery smolts earlier in the year when river flows are higher; and 2) releasing fewer hatchery smolts and increasing the number of yearlings released.

Earlier Release of Hatchery Smolts Volitionally releasing a portion of the fish prior to the minimal June flows may alleviate some of the problems resulting from reduced habitat availability and poor water quality. One concern with advancing the release date is whether fish have reached the smolt stage, and are ready to migrate directly to the ocean, minimizing their interaction with natural fish. DFG staff noted that under current conditions at IGH, some of the chinook that were spawned earliest in the season are at the smolt stage by early May and are segregated from fry spawned later in the season. A volitional release of certain groups could begin in early May after they have reached the smolt stage. The volitional release would increase the likelihood that the fish leaving the hatchery have reached the smolt stage. Another concern with advancing the release date to early May is that this is a critical time for natural fall chinook rearing in the mainstem Klamath River and the hatchery fish may compete for the limited available habitat.

Chinook eggs that are incubating at IGH are often exposed to extremely cold temperatures during the winter months (as low as 36EF by January 1). These cold temperatures increase incubation time, delay hatching and the time at which the fish smolt. Modification of the facility to heat the water used for incubation would decrease incubation time and result in earlier hatching and increase the number of chinook reaching the smolt stage in early May.

Increased Yearling Release and Decreased Smolt Release Releasing fewer smolts and more yearlings would relieve some of the hatchery-natural interactions that occur during the low-flow and poor water quality conditions present in the Klamath River during June and July. The time of the yearling release from IGH occurs during October 15 – November 15, which coincides with flow release increases from Iron Gate Dam, increased precipitation in the Klamath Basin, and substantially improved water quality conditions in the Klamath River. Interactions between hatchery and natural chinook would be minimized as a result of improved water quality and because most natural chinook would have already left the Klamath Basin.

Currently, IGH’s production of yearlings is at full capacity, with the use of an auxiliary facility located at Fall Creek, approximately 11 miles upstream of IGH. Water temperature at IGH during summer months, when yearlings are being reared, is less than optimal. The Fall Creek facility maintains optimal water temperature during the summer months and much of the water is not utilized. However, it is currently unclear how many additional yearlings could be reared from this water source. The facility at Fall Creek is now operated at capacity, so substantial modifications would be required to raise more yearlings at this facility. However, if funding becomes available, these modifications seem feasible. With the FERC process occurring over the next five years, it is possible that costs to upgrade the hatchery facilities could be a component of the mitigation responsibilities associated with the new license.

The potential effects of shifting some of the smolt production to yearling productions would need careful analysis, including changes in survival and maturation rates, size at age in ocean fisheries, emigration rates, increased domestication, and the costs associated with rearing fish for a longer period and upgrading facilities at Fall Creek and IGH.

Any hatchery operations (current or proposed) should be given thorough consideration regarding potential impacts to natural populations. Implementation of hatchery practices should occur in conjunction with an adaptive management approach, with the objective being to assess the impacts of hatchery operations on natural populations.

Recommendations:

1. The subcommittee identified a release strategy that may reduce impacts on natural populations by allowing smolts to be volitionally released at an earlier date. The release of chinook smolts could be accomplished by volitionally releasing each production group of fish as they reach 90 per pound (Table 1). Hatchery records show this begins around May 1st. The extension of the release window should result in lower numbers of hatchery fish being released into the Klamath River at any given time. Fish released in May should experience lower temperature and higher water flows. River flows are much more favorable in mid May, 2,500 to 3,000 cfs versus 1,000 cfs starting around June 15th. Because the need to crowd fish out to meet temperature, flow and time constraints would be less of a factor, the release would be more truly volitional. This modification of release strategy should reduce impacts on naturally produced stocks during periods of extremely poor water quality and improve the survival of hatchery produced smolts by allowing access to the lower water temperature and higher water flows available in late May.

Table 1. Proposed Changes to Stocking Goals and Constraints for Igh

		Stocking Goals and Constraints			
Species	Egg Allotment	Type	Number	Minimum Release Size	Target Release Dates
Chinook	10,000,000	Smolt	4,920,000	90/lb.	May 1 - June 15
		Yearling	1,080,000		Oct. 15 - Nov. 15

The DFG should explore the possibility of warming the water used at IGH in the egg incubation process in order to advance the hatching date for later lots of eggs. This would enable hatchery management to get the last group of chinook fingerlings closer to the 90 per pound smolt release size by the first week of June.

2. The presence of millions of hatchery smolts in the mainstem Klamath River during late spring and summer months may negatively impact natural populations. The subcommittee recommends that the DFG explore the desirability for expanding the chinook yearling program at IGH and reducing the chinook smolt production.

3. Advancing the release time of IGH fall chinook could potentially impact natural chinook that are rearing in the mainstem Klamath River during the month of May. Prior to implementing this strategy, or other major changes in rearing or release protocols, monitoring programs should be identified and implemented that will provide information on the effects of changes in rearing and release strategies, in particular on the interaction of hatchery and natural populations during the release period.

Iron Gate Hatchery Steelhead

Beginning in the 1989-90 season, steelhead have returned to IGH in substantially lower numbers compared to previous years. Returns dropped sharply to a low of 12 fish in the 1995-96 season and have since been just above or below 100 fish. It is the opinion of hatchery personnel that coincident with the poor returns, the fish that were spawned more resembled trout in size and coloration. Scale samples from adults returning to the hatchery in 1993 (BY 1990) were examined for growth patterns. Of the 11 marked fish, none showed an accelerated growth patten attributable to ocean or estuarine residence; of the 12 unmarked fish, 3 showed ocean growth patterns and consensus could not be reached on one sample. Since 1998 all steelhead released from IGH have been fin clipped. Only one marked fish has been captured at the out-migrant trap operated at Big Bar below Orleans on the Klamath River. Anglers do catch marked steelhead between the hatchery and Interstate 5. A possible explanation for the low returns and apparent residualization of the run is that during the drought of the late 1980s and early 1990s migrating yearlings encountered thermal barriers and either chose not to pass through elevated temperatures or died attempting the passage, with a resulting resident population created below the hatchery. Similar changes may also have occurred in naturally spawning populations.

<u>Recommendation</u>: The lack of indicators of ocean residence of hatchery "steelhead" in combination with the very low return numbers provide sufficient grounds to conclude that the IGH "steelhead" program may be producing rainbow trout and few, if any, steelhead. The subcommittee recommends that the DFG contiue efforts to identify the issues that have led to the residualization of the steelhead population and determine whether measures need to be taken to reverse this trend. If the problem continues, then a committee (including, but not limited to, the DFG, NMFS, and the Tribes) should be formed to determine the appropriate measures to address the problem. One option is to find an appropriate, naturally spawning, population of steelhead in the Klamath Basin from which brood stock could be taken to revitalize the steelhead program at IGH.

Trinity River Hatchery Spring Chinook

<u>Spring Fall Chinook Separation</u> Returning spring chinook usually begin to appear at the hatchery by mid-May of each year. The adult fish hold below the ladder through summer until the first week in September, when the spawning facility is opened to begin the new production year. Only a few females may be ripe on the initial spawn. Spring egg taking peaks in about three weeks, then declines until approximately October 12th. By this date, the early run is clearly over, and the ladder gate is dropped for a two week lull between the first and second runs. The fall run arrives as the spring wanes. Early fall fish are held, but usually succumb before egg maturity. Hatchery personnel report that run timing and phenotypic characteristics appear to provide good separation between fall and spring runs. There is currently a 2 week gap between spring and fall collection, during which fish cannot enter the hatchery.

The ladder is reopened at approximately October's end to receive the accumulating fresh run. The fall run spawning period extends through November and December, usually not past the new year. The ladder remains open continuously the second time, also trapping coho and winter steelhead.

Egg take is distributed throughout the two runs, collecting assigned allotments of three million spring eggs and six million fall eggs. Egg incubation is in proportion to the run magnitude and excess eggs are destroyed at earliest run size determination.

Although the spawning periods of the spring and fall run chinook do overlap, their spawning habitats were historically different, providing spacial separation of spawning populations. The spring run accessed to higher streams and the fall run utilized lower mainstem and tributaries. Because the historical spawning habitat of the spring run is no longer accessible, the potential for interbreeding of the two races has increased. The subcommittee recognizes and supports continued efforts to maintain a separation between spring and fall runs of chinook at the TRH.

Recommendation: The subcommittee recommended conducting an analysis of coded wire tag (CWT) recoveries from the early portion of the fall run to assess the presence of spring chinook and during the late portion of the spring run to assess the presence of fall run, in the respective pools of fish available for spawning. In addition, data should be gathered on whether CWT marked fish were used or rejected for spawning, based on phenotypic characteristics used by hatchery personnel to distinguish the two races. The analysis would then provide estimates of 1) the presence of fall run during spring brood stock collection; 2) the presence of spring run during fall run brood stock collection; and 3) how well phenotypic characteristics such as color serve to distinguish the races. If the analysis suggests a substantial presence of spring chinook during the early portion of the fall spawning season (or fall chinook during the late portion of the spring spawning season), and a significant number of one race being collected and spawned as the other, then the DFG should consider solutions such as increasing the 2 week gap between brood stock collection, or discarding of eggs collected during a period where CWT data indicated a larger than acceptable number of spawners collected from the non-target race. A population geneticist should be consulted to quantify what proportion of the run comprised of spring chinook should be considered "unacceptable", with the goal being to maintain genetic differences between spring and fall chinook populations.

Selection of Broodstock for Yearling Program The current Goals and Constraints for TRH require that egg collection for all species be representative of the entire run (date of return to hatchery). Accordingly, annual production is the progeny of adults having varied time of entry, spawning, time of egg hatching and juvenile growth.

These Goals and Constraints further require an annual production of one million spring chinook fingerlings (June release) and 400,000 yearlings (October release). Progeny from earlier returning fish are ponded first and consequently are more likely to reach the target fingerling release size of 90 fish/lb by the June release date. The fish from earlier spawning therefore tend to be utilized for the smolt releases and, until recently, the yearling production was often dominated by eggs which were collected towards the end of the hatchery recovery period (lots spawned in late September through early October). As yearlings generally experience higher survival rates from release to maturity than do fingerlings (Hankin 1990), it is possible that this kind of rearing and release practice may provide a selective advantage for later-returning spring chinook salmon.

For the past three years, fish for spring yearlings have been selected as smolts just prior to marking by the Hoopa Valley Tribe. Smolts for the spring yearling releases are selected from approximately the middle of the years production for the following reasons. For an accurate inventory, fish need to be about 100-150/lb. Fish that are larger than that, and subsequently released as yearlings, tend to have a large percentage of precocious males that will remain at the hatchery and fail to migrate down stream. Therefore larger (earlier ponded) fish are avoided for use in the yearling program. Smolts are inventoried by the standard practice of determining size of fish per pound then total number of pounds needed for the yearling production goal.

The alteration of run-timing as a result of hatchery practices has implications for both the genetic diversity and stock characteristics of the spring chinook race originally inhabiting the Trinity Basin. In addition, the effect may have significant management and allocation implications such as determining racial segregation (spring/fall chinook) for terminal fisheries and by extension for marine fisheries harvesting Klamath Basin chinook. The procedures used to allocate river harvest into spring or fall races include the analyses of coded wire tags. Over the past seven to eight years, river fisheries have reported an apparent protraction of the spring run timing for TRH spring chinook over that previously observed. Coded wire tag data serve as surrogate to estimate the proportions of naturally produced adult chinook belonging to the spring or fall races occurring in these fisheries. Accordingly, to the extent that protracted run timing is an artifact of hatchery practices, river fisheries may underestimate true fall chinook impacts and bias estimates of ocean harvest rates.

Recommendation: For both spring and fall chinook, the numbers of fish held for release as smolts and as yearlings should reflect the numbers of fish returning at different times of the run, in the same way that eggs are selected from all components of the run.

Marking

A time series of accurate estimates of the contribution of hatchery fish to spawning escapement would be a valuable indicator of the status of naturally spawning populations. Although annual estimates of naturally spawning fish and hatchery returns are available for Klamath-Trinity Basin salmon, unknown numbers of hatchery fish spawn naturally. Variable marking rates of hatchery production make estimates of the proportion of hatchery fish in the run difficult. A constant fractional marking program will likely be implemented at TRH (Zajanc and Hankin 1998, Hankin and Newman 1999). Since few Klamath fish stray into the Trinity, a coordinated program with IGH may not be necessary to estimate the proportion of hatchery fish in the Trinity. However, in order to estimate the proportion of hatchery fish in the Klamath Trinity Basin, adults would need to be sampled as they entered the Klamath River and a coordinated marking program between TRH and IGH would be necessary. Appropriate monitoring methods on the major tributaries to the Klamath and Trinity would be necessary for sub-basin estimates of hatchery contributions.

Recommendation: The subcommittee endorsed the concept of a coordinated constant fractional marking and representational marking of all lots of smolt and yearling chinook releases at both IGH and TRH, recognizing that concerns regarding the logistics of counting and marking a substantial fraction of the IGH fall chinook production would need to be addressed.

Monitoring

Little information is available on either the status of wild coho populations or the extent of straying of hatchery reared coho into natural spawning areas. Although the operation of weirs throughout the entire run time of coho can be difficult or impossible, there may be certain tributaries where flows would allow an adult census. Where possible, monitoring strategies should be identified that would provide better information on the status of naturally spawning coho in the Klamath Trinity Basins. The subcommittee agreed that additional efforts to genetically characterize hatchery and wild coho stocks within the Klamath Trinity Basins would be useful for any future decisions regarding the use of hatchery stocks or non-hatchery brood stock in recovery efforts

References

Hankin, D.G. 1990. Effects of month of release of hatchery-reared chinook salmon on size at age, maturation schedule, and fishery contribution. Information Report Number 90-4. Oregon Department of Fish and Wildlife, Portland, Oregon.

Hankin, D.G., and K. Newman. 1999. Improved methods for assessment of the contribution of hatcheries to production of chinook salmon and seelhead in the Klamath Trinity river system. Contract report, Hoopa Valley Tribal Fisheries Department, Hoopa, CA.

Solicitor, U.S. Department of the Interior (DOI). 1993. Fishing Rights of the Yurok and Hoopa Valley Tribes. Solicitor Memorandum M-36979

Zajanc, D., and D.G. Hankin. 1998. A detailed review of the annual production cycle at Trinity River hatchery: with recommendations for changes in hatchery practices that would improve representativeness of marking and accuracy of estimation of numbers release. Contract report, Hoopa Valley Tribal Fisheries Department, Hoopa, CA.

Appendix III. Membership of Joint Hatchery Review Committee and Attendance at Meetings. "Other Attendees" attended at least two committee meetings.

Members of the Committee
Pete Adams, NMFS
Alan Baracco, DFG
Bruce Barngrover (until 6/30/00), DFG
Tim Farley, DFG (Co-Chair)
Svein Fougner, NMFS (Co-Chair)
Dan Free (until 10/31/00), NMFS
Royce Gunther (as of 7/1/00), DFG
Craig Heberer, NMFS
Bruce MacFarlane, NMFS
Dan Viele, NMFS
Craig Wingert, NMFS
Shirley Witalis (as of 11/1/00), NMFS

Subcommittee on Off-site Release and Straying
Dan Free, NMFS
Scott Hamelberg, USFWS
Craig Heberer, NMFS
Bob Kano, DFG
Steve Lindley, NMFS
Wade Sinnen, DFG
Jim Smith, USFWS (Chair)
Dan Viele, NMFS

Subcommittee on Klamath Trinity Issues
Dave Hankin, Hoopa Tribe
Dave Hillemeier, Yurok Tribe
George Kautsky, Hoopa Tribe
Neil Manji, DFG
Pat Overton, DFG
Mike Orcutt, Hoopa Tribe
Gary Ramsden, DFG
Kim Rushton, DFG
Dan Viele, NMFS (Chair)

Other Attendees
Rich Bryan, DFG
Bill Cox, DFG
Rich Dixon, DFG
Roger Ellis, DFG
Gene Fleming, DFG
Anna Kastner, DFG
Dan Logan, NMFS
Dennis McEwan, DFG
Mary Ellen Mueller, USFWS
Armando Quinones, DFG
Gary Stacey, DFG
Tresa Veek, DFG
Larry Week, DFG
Terry West, DFG
David Woodbury, NMFS

Appendix IV. List of Major Handouts at Meetings.

CFM Implementation Plan - a CALFED Ecosystem Restoration Projects and Programs proposal solicitation for doing constant fractional marking of chinook salmon at Central Valeey hatcheries.

A Conceptual Framework for Conservation Hatchery Strategies for Pacific Salmonids (NOAA Technical Memorandum NMFS-NWFSC-38)

Upper Eel River Chinook Emergency Hatchery Program

Hatchery and Genetic Management Plan (HGMP) Template

California Department of Fish and Game Inland Salmon (chinook) Program

Thermal Otolith Marking of Trinity River Hatchery Production

Revised Klamath River Basin Fall Chinook Salmon Run Size, In-River Harvest and Spawner Escapement – 1998 Season

Noyo River Fisheries Station Coho Salmon Management Plan

Alternative Methods of Propagation of Spring-Run Chinook, Feather River Hatchery

DFG Cooperative Fish Rearing Program - Status Report

Appendix V. Production and Release Data for Salmon and Steelhead Hatcheries in California. (*source: DFG-NMFS Hatchery Review documentation; personal communication with hatchery managers*).

Hatchery	Species Run	Production Goals	Brood 1998 - Release 1999 Production	Tags/Marks	Size and Time of Release	Locations for Release
Coleman NFH	late-fall chinook	1,000,000 smolts	1,102,540	100% CWT since BY 92	13-14/lb. (Nov.-Jan.)	released primarily in Battle Creek; some experimental releases down river and in the Delta.
Coleman NFH	fall chinook	12,000,000 smolts	13,030,993 smolts + 755,073 fry (fry program discontinued after 99 year releases)	~8% CWT since BY 95; BY 98-99 Release: 1,004,914 CWT	smolts~90/lb. (Apr.) fry =300-500/lb.(March)	smolts released primarily in Battle Creek; fry released below RBDD
Coleman NFH	steelhead	600,000 smolts	496,525	100% ad-clip since BY 98	~4/lb. (Jan.)	75% in Sac. R. at Balls Ferry and 25% in Battle Creek
Coleman NFH	winter-run chinook	200,000 smolts	153,000	100% CWT since BY 91	~85 mm.(Jan.)	trucked to Sac. R. near Redding (Caldwell Park)
Feather River	spring chinook	5,000,000 smolts	1,850,000	~14% CWT (301,200 for 99 Release)	40-60/lb. (May-July)	trucked to San Pablo Bay
Feather River	fall chinook (regular production)	6,000,000 smolts	7,921,787	~5% CWT (301,600 for 99 Release)	40-60/lb. (Apr.1-Aug.15)	trucked to San Pablo Bay and study release sites in Delta
Feather River	fall chinook (Salmon Stamp Program)	2,000,000 post-smolts	2,098,920	unmarked	~30/lb. (May-July)	trucked to San Pablo Bay
Feather River	fall chinook (inland chinook program)	600,000 yearlings	BY 99-00 Release: 566,669 were destroyed due to IHN	unmarked	8-10/lb. (November)	trucked to local lakes
Feather River	fall chinook (for trib. stocking)	~750,000 fry if excess production available	500,000	unmarked	~500/lb. (Jan.-Feb.)	trucked to various tributaries
Feather River	steelhead	450,000 yearlings	345,810	100% ad-clip	~4/lb. (Jan.-Feb.)	trucked to Gridley
Iron Gate	coho	75,000 yearlings	BY 98-00 Release: 77,147	75,460 with left max.clips	~7/lb. (Mar.15-May 1)	released in Klamath R. at hatchery
Iron Gate	steelhead	200,000 yearlings	37,080	35,970 with adipose and left-max clips	~12/lb. (Mar.15-May 1)	released into Klamath R. at hatchery facility.
Iron Gate	fall chinook	4,920,000 smolts 1,080,000 yearlings	4,965,229 smolts 1,122,127 yearlings	smolts ~200,000 CWT yearlings ~100,000 CWT	smolts~ 90/lb. (June 1-15) yearlings~10/lb. (Nov.1-15)	released in Klamath R. at hatchery facility.
Mad River	steelhead	250,000 yearlings	BY 99-00 Release: 368,082	100% ad-clip	4-8/lb. (March-May)	released in Mad R. at hatchery

Hatchery	Species Run	Production Goals	Brood 1998 - Release 1999 Production	Tags/Marks	Size and Time of Release	Locations for Release
Mad River	fall chinook (Mad R. strain)	4,000,000 smolts 1,000,000 yearlings	21,600 yearlings	unmarked	smolts~60/lb. (May-June) yearlings 8-10/lb. (Oct.)	trucked to the Mad R. estuary
Mad River	fall chinook (rearing for Upper Eel River Chinook Emergency Hatchery Program)	12,500 yearlings 12,500 pre-smolts (production rearing split between Mad R. and Warm Springs)	14,490 yearlings	100% CWT	yearlings=10-15/lb. (Oct.-Nov.)	trucked to Van Arsdale station for acclimation (~2 weeks) and release into upper mainstem Eel R.
Merced River	fall chinook	960,000 smolts or up to 300,000 yearlings (only produce yearlings if adult return very low)	913,329 smolts	666,602 CWT and 130,786 dye marked;	smolts 70-90/lb. (Apr.1-June 30); yearlings 6-10/lb. (Oct.1-Dec.30)	~60% volitionally released at hatchery; ~40% trucked to specific sites for study releases. For BY 98-99 Release: 44% into Merced R.; 12% into Tuolumne R.; 12% in Stanislaus R.; 32% San Joaquin R.
Mokelumne River	fall chinook (mitigation production - experimental releases)	1,000,000 smolts	1,000,000	~300,000 CWT	40-75/lb. (May-June)	~100,000 CWT at New Hope, Moke, R.; ~100,000 CWT at Chips Isl., San Joaquin R.; ~100,000 CWT + remaining unmarked smolts at Thorton, Moke. R.
Mokelumne River	fall chinook (Salmon Stamp Program)	2,000,000 post-smolts	1,600,000	~100,000 CWT	25-30/lb. (Apr.15-July 31)	trucked to San Pablo Bay
Mokelumne River	fall chinook (mitigation production for in-river releases)	500,000 yearlings	422,000	100% CWT	~10/lb. (Sept.-Oct.)	released in Mokelumne R.
Mokelumne River	steelhead (eggs and/or fry from Nimbus and Feather R. hatcheries)	100,000 yearlings (reared at Moke. hatchery)	102,440	100% ad-clip	4/lb. (Jan.-Feb.)	released in Lower Mokelumne R.
Nimbus	steelhead	430,000 yearlings	400,060	100% ad-clip	4/lb. (Jan.-Feb.)	trucked to Sac. R. at/or below Discovery Park
Nimbus	fall chinook	4,000,000 smolts	4,486,000 smolts	unmarked	40-60/lb. (Apr. 15-July 31)	trucked to San Pablo Bay
Nimbus	fall chinook (for ocean net pens)	? smolts	243,808	52,008 CWT - Tyee Club fish, remainder unmarked	30-70/lb. (May-June)	trucked to ocean net pen holding facilities
Nimbus	fall chinook (reared for Mokelumne hatchery)	up to 4,000,000 eggs?	200,680 fingerlings	unmarked	~200/lb. (May)	trucked to Mokelumne hatchery for acclimation and release

Hatchery	Species Run	Production Goals	Brood 1998 - Release 1999 Production	Tags/Marks	Size and Time of Release	Locations for Release
Nimbus	fall chinook (tributary plants)	500,000 fingerlings	540,870	unmarked	180-300/lb.(April)	trucked to Sac. R. tributaries
Trinity River	spring chinook	1,000,000 smolts 400,000 yearlings	959,000 smolts 399,000 yearlings	smolts ~16% CWT; yearlings ~35% CWT	smolts~50/lb. (June 1-15); yearlings 10-12/lb. (Oct.1-15).	volitional at hatchery; early lots reach size requirements first and are released as smolts, later ones serve as yearlings
Trinity River	fall chinook	2,000,000 smolts 900,00 yearlings	1,991,000 smolts 993,000 yearlings	smolts~10% CWT yearlings~35% CWT	smolts~90/lb. (June 1-15); yearlings 10-12/lb. (Oct. 1-15).	volitional at hatchery; early lots reach size requirements first and are released as smolts, with later ones serving as yearlings
Trinity River	coho	500,000 yearlings	493,700	100% right max. clip	10-20/lb. (Mar.15-May 1).	volitional at hatchery facility
Trinity River	steelhead	800,000 yearlings	382,900	100% ad-clip	7/lb. (Mar.15-May 1). Fish < 6 inches held for additional year and released as 2 yr. olds. Have not done this for several years.	volitional at hatchery facility
Warm Springs Russian River (Don Clausen Hatchery)	fall chinook (for Dry Creek strain)	1,000,000 yearlings	No production past two years	No production past two years	~10/lb. (Oct.-Nov.)	100 yards to 3 miles downstream of hatchery facility
Warm Springs Russian River (Van Arsdale - Eel River Fish)	fall chinook (rearing for Upper Eel River Chinook Emergency Hatchery Program)	37,500 yearlings 37,500 pre-smolts (production rearing split between Mad R. and Warm Springs)	45,100 yearlings	100% CWT	yearlings =10-15/lb. (Oct.-Nov.) pre-smolts reared for 40-60 days.	trucked to Van Arsdale for acclimation and release into the upper mainstem Eel R.
Warm Springs (Don Clausen Hatchery)	Steelhead (for Dry Creek strain)	300,000 yearlings	302,005	100% ad-clip	~4/lb. (Dec.-Apr.). In Dec., grade steelhead and release all fish 4.0/lb. or larger. Release all others no later than April regardless of size.	trucked to Dry Creek + 40,000 lb. trucked to Coyote Valley Fish Facility for release into Russian R.
Coyote Valley Fish Facility	Steelhead (reared at WSH but held 30 days at Coyote to imprint)	200,000 yearlings	229,451	100% ad-clip	~4/lb. Jan.- March.	volitionally in East Fork Russian R. above confluence with Russian R.

Table notes: The terms smolt, post-smolt, and yearling denote size. In the case of smolt, the size is what has been determined by DFG staff to correlate with the ability and propensity of those fish to migrate upon release.
The term "post-smolt" was coined to differentiate the larger fish that are released specifically for ocean enhancement.

Appendix VI. Summary of Public Comments on Draft Report

Through press releases, the public was notified that copies of this report were available at DFG and NMFS web sites. This occurred on July 13, 2001. A deadline for comments was set as August 17, 2001. Subsequently, requests to extend the deadline were received (some were included in the correspondence in this summary), and a new deadline was set for September 14, 2001.

Following is a summary of the main points from each commenter. Editorial and grammatical questions and suggestions have not been included (but were considered by the Committee in preparing the final report). Dates of each correspondence are included in parentheses, and comments are presented in chronological order.

1. Dr. David Hankin, Professor, Humboldt State University. (7/30)
Dr. Hankin reviewed the main report only (not the appendices). He was in general agreement with the conclusions and recommendations of the report. His comments expressed the following:

- strong support for recommendations regarding 1) periodic review of hatchery production levels; 2) development of adequate Central Valley sampling programs; and 3) development of constant fractional marking program.
- concerns regarding off-site release are correctly identified in the report; therefore the recommendation to "consider" ceasing trucking downstream migrants and releasing salmon smolts at the hatchery was weak. He recommended that all hatchery releases should be made on-site and that the report recommendation should read at a minimum read: "CDFG should shift emphasis from off-site release to on-site (near hatcheries) release, especially as conditions for outmigration in the mainstem Sacramento River and delta improve in the future."
- the report doesn't mention the possibility of competition (in freshwater and at ocean entry) between large numbers of hatchery-released smolts and natural smolts.
- the cooperative rearing programs need more scrutiny and should be required to produce HGMPs.
- the report is weak with respect to hatchery mating and rearing practices and resulting selection and domestication effects; for example, the report should at least identify issues associated with the use of jacks as broodstock.

2. Ms. Marla Morrissey. (8/7)
Ms. Morrissey asked the question, "will artificial ocean-based salmon hatcheries affect So. Central Calif. steelhead?" She had no direct comments on the report.

3. Mr. Jimmy Smith, Supervisor, Humboldt County. (8/10)
Mr. Smith's main points on the report were:

- recommendations to curtail trucking would have devastating impacts on recreational and commercial fishing.
- co-ordinating water management practices to maximize immigration survival should receive primary emphasis.
- the report should emphasize the successes of the hatchery system.

4. Mr. David Goldberg, Manager, California Salmon Council. (8/15)
Mr. Goldberg's comments were:

- the recommendation to curtail trucking of salmon juveniles is distressing. This will reduce salmon survival rates.
- the Department should be prepared to increase the take of hatchery-produced adults instead of (or in anticipation of) reducing the survival of resulting juveniles.

5. Mr. W. F. "Zeke" Grader, Jr, Executive Director, Pacific Coast Federation of Fishermen's Associations. (8/22)
Mr. Grader expressed the following points:

- PCFFA agrees with many of the report's findings and recommendations.
- they specifically supported the recommendations for changes in Delta water operations and rigid genetic protocols for all salmonid hatcheries.
- they agree that straying of returning adult salmon is a valid concern, but they do not agree that cessation of trucking is the correct solution or only alternative. PCFFA suggests that other alternatives be explored that would provide benefits to the fisheries but reduce straying, for example release of small numbers of hatchery fish at the hatchery , with the remainder trucked to sites in the Delta or Bay (e.g. the Petaluma River) for acclimation and release.

6. Mr. Duncan MacLean, President, Half Moon Bay Fish Marketing Association. (8/23)
Mr. MacLean stated the following:

- the report is "seemingly focused on reducing hatchery production and eludes to reduce harvest as justification for it." He adds that harvest should not be a consideration in the report.
- he doesn't believe that the report delves deeply enough into present hatchery practices and key elements there that could further protect genetic diversity and biodiversity.
- he agrees that constant fractional marking would be a useful tool.
- he doesn't feel that eliminating trucking should occur unless the real causes of straying are better known.
- release timing needs discussion and he suggests that maybe we should be working toward one salmon run in the Central Valley.
- if mitigation were properly instituted, there would not likely be endangered species issues.

7. Mr. Jim Brobeck, Chico citizen. (8/26)
Mr. Brobeck supported the goals of the report, specifically its "precautionary approach...to support wild strains of salmon and steelhead".

8. Mr. Gene Gutt. (8/28)
Mr. Gutt asked why the distribution of the report was "so exclusive".

9. Mr. Jim Gaumer, Chico resident. (8/28)
Mr. Gaumer disagreed with the idea of no longer transporting salmon smolts downstream. He felt that straying is a natural phenomenon, and that releasing smolts at the hatchery will mean less salmon for commercial and sport fishermen.

10. Mr. Adam Howard. (8/29)
Mr. Howard disagrees with the recommendations to discontinue supplying Mokelumne River Hatchery with steelhead eggs from the American River. He also disagreed with “stopping the downstream transport of smolts”.

11. Mr. Felix Smith, retired Federal biologist. (8/29)
Mr. Smith expressed appreciation for the report’s findings, conclusions and recommendations. He had the following specific suggestions to increase the success of future hatchery and natural production and restoration activities:

- water management practices are crucial to the immigration and emigration of salmonids into and from the Central Valley. Favorable instream water conditions must be maintained and protected as well.
- water exports in the Central Valley must be timed to keep salmon migrants out of the Central and South Delta.
- enhancement salmon raised with salmon stamp funds could be released in estuarine areas that don’t have natural salmon runs - e.g., Morro Bay, near the Noyo River, or in Bodega bay.
- mitigation hatcheries must meet their mitigation requirements. In addition, small hatcheries or egg-taking stations could be used to build up local runs or populations.
- all ESA-listed salmonids reared in hatcheries should be marked.
- voluntary emigration of smolts from hatcheries should be facilitated.
- there should be greater focus on the design and operation of the Mokelumne River Hatchery to produce healthy and better naturalized salmon and steelhead.

12. Mr. Robert Miller, President, Crab Boat Owners Association. (8/31)
Mr. Miller expressed concern about the “proposal to curtail trucking of hatchery juveniles downstream to safer release sites”.

13. Patrick Kelly, Chico resident. (9/10)
Mr. Kelly stated the following:

- he is opposed to terminating the downstream trucking of salmon from the Feather River Hatchery, because 1) the hatchery doesn’t currently compensate for habitat lost above Oroville Dam and 2) present problems in the Delta due to water transfers may not be solved.
- he does not believe that there are distinct fall- and spring-run salmon at that hatchery. He referenced Hedgecock’s Bodega Marine Lab work on that subject.

14. Mr. W. F. “Zeke” Grader, Jr, Executive Director, Pacific Coast Federation of Fishermen’s Associations. (9/14)
This is a follow-on letter from Mr. Grader that included a report done by a PCFFA biological consultant, Mr. William Kier. Mr. Grader reiterates his (and references Mr. Kier’s) agreement with most of the report’s recommendations. However, they both conclude that there is no current evidence of genetic harm caused by the adult straying of trucked hatchery smolts.

- Mr. Kier finds no evidence of genetic harm upon which to justify the recommendation that the release of hatchery salmon in the Delta be terminated. Citing Banks et al. 2000, he

concludes the remaining genetic diversity among Central Valley fall chinook is too little to worry about.
- To the contrary, the straying of salmon into unoccupied habitat might be one of the most powerful contributions to genetic diversity at work in the Central Valley.
- The impact on ocean salmon fisheries of ending release of smolts in the western Delta would be dramatic, likely devastating.
- Although the report asserts that "the risks posed to natural populations appear to outweigh the benefits from increased contribution to fisheries", there was no analysis weighing the benefits and costs, social or biological, of the report's recommendations.

15. Mr. Dave Bitts, Vice President, Pacific Coast Federation of Fishermen's Associations. (9/17)
- The report does not make a cogent case for the long-term benefits of ending trucking; the benefits are hypothetical and the cost to fisheries are real and immediate.
- The report ignores the reasons for the survival differential between off-site and on-site releases; there must be a greater effort to protect downstream migrating naturally-produced salmonids in light of the fact that there is much better survival of smolts transported downstream (and presumably around sources of mortality).

16. Mr. Frederick A. Meyer, retired State biologist. (Undated)

Mr. Meyer states that the report incorrectly treats possible problems with hatcheries as real ones, and that some definitions are unclear. Specifically,
- since there are no definitive genetic studies showing differences in Central Valley fall-run stocks, "in-river" hatchery releases are not justified. Survival could be so low as to cause loss of a year-class.
- because of constant mixing of river- and hatchery-produced fish, the terms "natural" and "hatchery-produced" salmon are meaningless.
- straying due to water management regimes and practices, uneven angler effort, the small size of fish released at Coleman National Fish Hatchery, and hatchery attraction flows deserve greater scrutiny.
- if there are no fall-run differences, why not plant surplus salmon fry?
- separating Feather River spring-run from fall-run is a good idea. So is fractional marking at all hatcheries.
- without Nimbus steelhead eggs, there may not be a steelhead run in the Mokelumne River.
- he questions the rationale behind phasing out the Eel River strain of steelhead in the American River.

Committee response to the above comments

The Committee thanks all the reviewers for taking the time to read the report and to prepare comments and send them to us. The Committee discussed all of the main points raised in the comments and made some changes in the report - primarily for clarification purposes. In addition, the Committee has the following responses on specific issues:

Cooperative rearing programs - the Committee discussed this topic at length. There is agreement that these programs probably need additional oversight, but there was no agreement on what that would entail or who would do it (DFG, NMFS, or both).

Broodstock selection and mating protocols - the Committee recognized the importance of this topic and it received considerable attention in discussions. A subcommittee was contemplated (but wasn't formed), and at one point it had a much longer section in the report. Because there are likely to be hatchery-specific considerations, it was decided that decisions regarding broodstock selection and mating protocols should be included in individual hatchery HGMPs.

Downstream release of hatchery smolts - Some reviewers supported the report recommendations, others did not, and several reviewers questioned the importance of the genetic effects of high rates of adult salmon straying in Central Valley streams. The Committee recognized the uncertainties surrounding this topic, but it felt a need to be conservative because there are listed and candidate species involved. Those in favor of continued releases in the western Delta and below expressed serious concern that the increased mortality associated with requiring hatchery smolts to transit the Delta (rather than trucking them around) would have considerable, perhaps devastating, effects on sport and commercial fisheries, and that the report provided no analysis or consideration of the potential social and economic effects of the recommendation. Few of the reviewers, however, commented on the (perhaps subtle) difference between the recommendations for spring and fall runs.

Spring chinook - the Committee's recommendation for on-site release of Feather River Hatchery spring chinook is consistent with, and supports, the independent recommendation contained in the Department's 1998 status review of spring chinook in the Sacramento River drainage.

Fall chinook - the Committee's recommendation for consideration of on-site release reflects the different status of naturally spawning fall and spring-run populations in the Central Valley as well as concern among Committee members regarding the effects of reduced contribution rates to ocean harvest that will result from on-site release. While there was agreement that downstream releases increase contribution to fisheries, the magnitude of the increase is uncertain. The potential effects on the fishing industry of implementing the recommendation are therefore difficult to predict, primarily because of lack of information regarding the effects of these releases under present day conditions. None of the data in the report showing relative contribution rates to fisheries of on- and off-site releases is more recent than the 1980 brood year. Of the studies which led to the Department's decision to truck fish, only one (Sholes and Hallock 1979), which reported a decrease in ocean contribution rates of fish released at Rio Vista relative to release at the Feather River Hatchery, was regarded as sufficiently rigorous to be published as a scientific report. Since 1992, Coleman National Fish Hatchery has released all of its fall chinook production in Battle Creek or at Red Bluff Diversion Dam. The USFWS estimates that between 1992 and 1998, Coleman fall chinook accounted, on average, for 20% of the total chinook harvest south of Point Arena. More recent data do exist for Feather River Hatchery fall chinook releases at various sites. These and any further findings on the genetics of Central Valley salmon will be considered as the Department weighs the Committee's recommendations and explores alternatives and options for appropriate release sites and ways to reduce straying. Additional experiments and pilot studies are likely. The Committee envisions that even if the eventual decision is made to release smolts at or near hatcheries, there may be situations when trucking will be appropriate - e.g., during severe droughts.

Genetic Differentiation - Several commenters seized on the lack of observed genetic differentiation among Central Valley fall chinook populations to apparently conclude that genetic diversity among Central Valley fall chinook populations is not worth worrying about. As efforts proceed to repopulate restoration-project streams such as Battle Creek, the likelihood of establishing productive, locally adapted, populations is diminished if the populations must contend with continued high numbers of straying hatchery fish.